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FINAL REPORT

HINDCASTING EXTREME BEAUFORT SEA STORMS

ATMOSPHERIC ENVIRONMENT SERVICE

DOWNSVIEW, ONTARIO

1989

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FINAL REPORT

**HINDCASTING EXTREME
BEAUFORT SEA STORMS**

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Abstract

This report describes procedures that were used to hindcast marine winds for 14 severe Beaufort Sea storms on a 20-minute latitude by 60 minute longitude grid. These procedures were developed by MacLaren PlanSearch Ltd. and Dr. V. Cardone of Oceanweather Inc. and are incorporated into a Beaufort Sea Storm Hindcast System implemented on a Compac 386 microcomputer. This provides the capability of hindcasting other severe storms as necessary.

Special modifications were made to the Marine Planetary Boundary Layer Model for winter Arctic conditions, which are characterized by low inversion heights and large geostrophic/surface wind turning angles, and for marginal ice zone conditions. These modifications follow the work of Dr. J. Overland (1985).

Résumé

Le présent rapport décrit les méthodes utilisées pour prévoir a posteriori les vents marins de 14 violentes tempêtes de la mer de Beaufort dans une grille de 20 minutes de latitude sur 60 minutes de longitude. Mises au point par MacLaren PlanSearch Ltd. et V. Cardone, d'Oceanweather Inc., ces méthodes sont incorporées au Système de prévision a posteriori des tempêtes de la mer de Beaufort mis en application sur un micro-ordinateur Compac 386. On peut ainsi, si nécessaire, prévoir a posteriori d'autres violentes tempêtes.

On a apporté des modifications spéciales au Modèle de la couche limite planétaire marine pour le temps arctique d'hiver, caractérisé par de faibles altitudes d'inversion et de grands angles de rotation formés par le vent géostrophique et le vent de surface, ainsi que pour l'état de la zone marginale des glaces. Ces modifications découlent du travail de J. Overland (1985).

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1.0

INTRODUCTION

In a previous study by MacLaren Plansearch Limited (MPL) in association with Oceanweather Inc., twenty Beaufort Sea summer (i.e. open water season) storms were hindcast. This work was described in detail in MacLaren Plansearch Limited (1987), see also Agnew et al. (1989). The wind fields for these twenty storms were hindcast for a period from 1976 to 1985. This study is an extension of that work involving hindcasting an additional 10 winter storms and 4 summer storms for the pre-1976 period.

A second objective of this work was to implement the software developed for this study on AES Arctic Section's COMPAQ 386/20 microcomputer for their in-house use.

This report provides a brief description of the methodology, analysis procedures, and presents some of the hindcast results. It also provides discussions and recommendations for future work.

The software documentation is provided in a separate report entitled "Computer Program User's Guide", August 1989.

2.0

ANALYSIS METHODS

In the previous study, the wind fields were created from a blend of objective analysis and kinematic analysis. The model domain used in that study is shown in Figure 1.

However, for the present study, none of the selected storms had BWO (Beaufort Weather Office) charts and marine data were very sparse to warrant the use of kinematic analysis. Therefore, as requested by the Scientific Authority, the kinematic analysis was not performed in the present study.

2.1

OBJECTIVE ANALYSIS

The six-hourly synoptic weather charts from the Canadian Meteorological Centre (CMC) and the Arctic Weather Centre (AWC) were used in the present study. The CMC synoptic weather charts were used when AWC charts were not available. In addition, the marine observations and wind records from the six coastal land stations found in AES archives were obtained and used in the re-analysis of the pressure fields. The six coastal stations used were: Barter Island, Komakulk Beach, Shingle Point, Tuktoyaktuk, Caper Parry and Sachs Harbour. All given charts were re-analyzed using all available observations.

The above maps were then digitized using a software developed by MacLaren Plansearch, which utilizes AutoCAD package on a COMPAQ 386 P.C. The software has the capability of viewing the digitized isobars, editing the chart, etc. Once the user is satisfied with the digitized pressure fields, the software can then be run to convert the isobaric contours from chart cartesian x, y axis to latitude and longitude values, and write them onto a data file with format acceptable to the wind field specification program (PRESTO_WIND) which is described in the next section. The above software is also described in the User's Guide submitted separately to the AES.

Figure 2 shows an example of a digitized surface pressure chart.

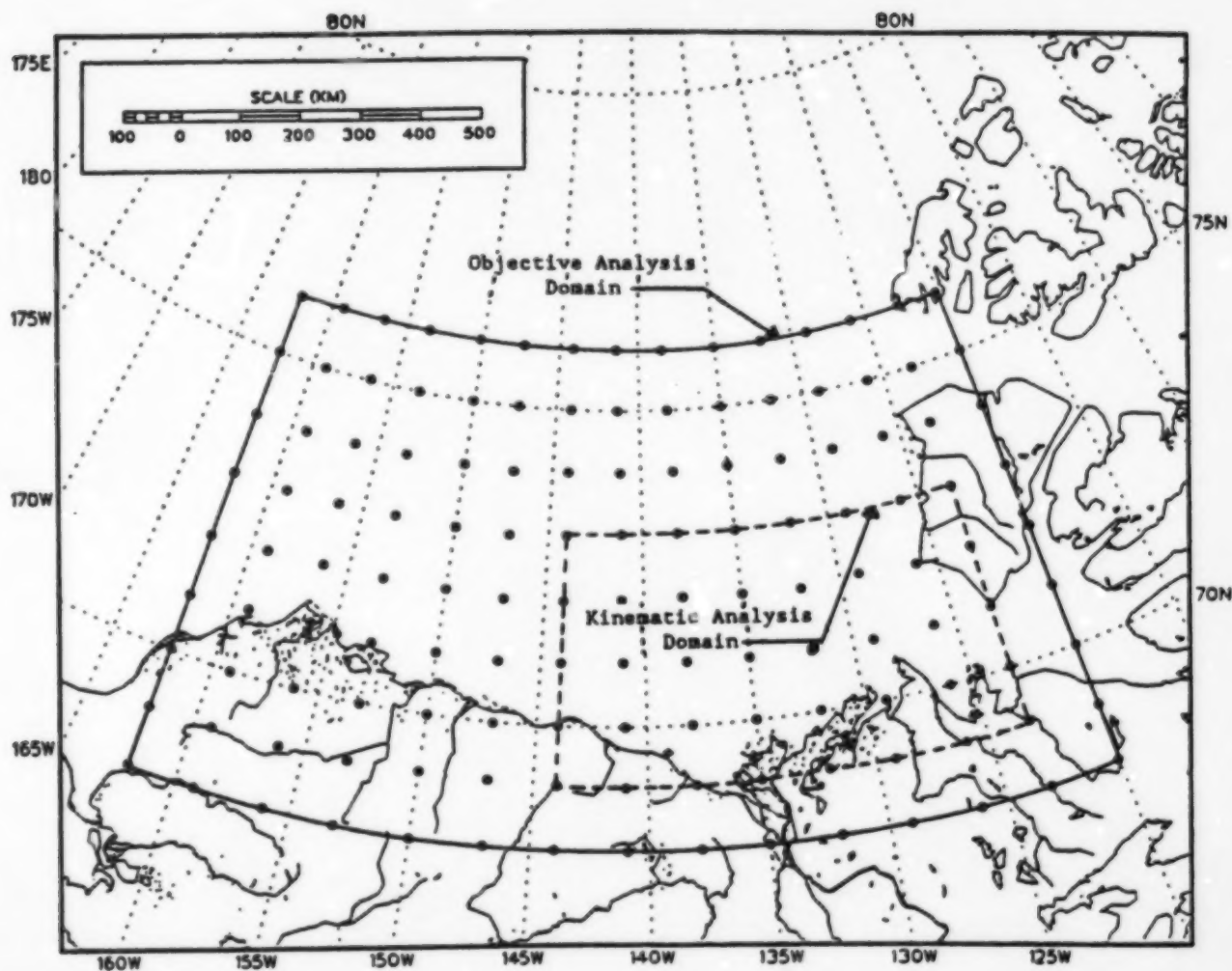


Figure 1. Wind Hindcast Model Grid

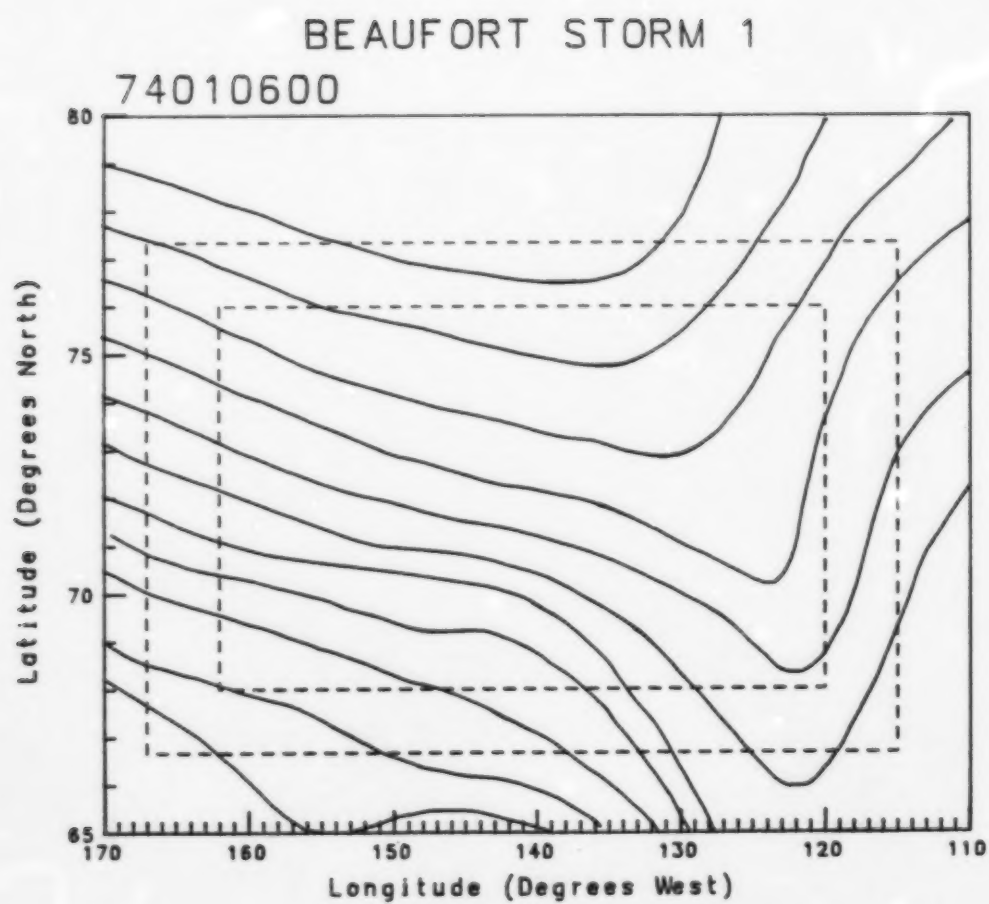


Figure 2. Example of digitized pressure maps

2.2

WIND FIELD SPECIFICATION PROGRAM

2.2.1

General Description

A computer program was developed to specify the wind fields on a latitude-longitude grid with points spaced 20-minutes in latitude by 60-minutes in longitude over the domain 68 degrees to 76 degrees North latitude and 120 degrees to 162 degrees West longitude (Figure 1). The program is designed to calculate grid fields for up to 41 consecutive 6-hourly maps, providing a maximum hindcast period of 10 days.

The program consists of two basic parts. The first part, executed in program PRESTO_WIND, computes winds at each grid point from pressure fields supplied as input in the form of isobar coordinates, and grid point specific categorical descriptions of the surface drag regime (i.e. open water, smooth ice, rough ice, and Arctic winter) and over-water thermal stratification (i.e. the air-sea temperature difference). The output of this program consists of fields of wind speed and direction on the whole grid, a separate file of the maximum wind on the grid for each map, a file of the wind speed and direction at up to six selected points each map, and a file of wind components to be used (optionally) by the program which accepts manually entered winds over a subdomain of the whole grid.

The second part of the program, executed in program KINEMA, accepts winds specified at grid points within the domain 68°N to 76°N, 152°W to 120°W, at grid intervals of up to 1-degree in latitude and 2-degrees in longitude, may be entered. Over the subdomain at which winds are entered, the winds are interpolated to every grid point (if they were entered at coarser resolution) where they overwrite the winds calculated in PRESTO_WIND. The output of KINEMA consists of fields of wind speed and direction on the whole grid, and files of wind maxima, and winds at selected grid points in the same format as produced by PRESTO_WIND. In the previous MacLaren Plansearch study, the kinematic analysis domain extended from 69°N to 73°N and 123°W to 144°W (i.e. covering most of the open water area). Although the program delivered to AES contains the

kinematic analysis subprogram (KINEMA), it was not utilized in this study as mentioned previously, i.e. only objective analysis using PRESTO_WIND was applied.

2.2.2

Theoretical Basis of the Wind Program

PRESTO_WIND

The basic approach adopted in the program is the same as that described by Cardone et al. (1980) for the specification of surface winds over strictly open-water basins. That is, first, a steady state, single point, marine planetary boundary layer model (MPBL) is used to calculate winds at each grid point on a grid on which the pressure, air and sea temperature fields have been prescribed. Then, over a limited part of the whole grid, winds which have been externally supplied, usually as hand gridded from manually derived kinematic (streamline-isotach) analyses, are accepted and supersede the winds derived from the pressure field. In fact, over open-water, or water with perhaps less than four-tenths ice cover, the program delivered works just as the standard open-ocean version of the MPBL.

The MPBL requires in general the following input at each grid point:

- sea level pressure gradient
- horizontal air temperature gradient (the baroclinicity)
- air-sea temperature difference.

In the program, air-sea temperature differences may be specified independently at each grid point using NAMELIST input for each map. At points at which the air-sea temperature is not prescribed, the program has a default facility whereby the air-sea temperature difference is set according to the local pressure-gradient (equivalently the geostrophic wind) direction.

The MPBL provides unbiased and reasonably accurate surface winds over open water when accurate inputs are specified and acceleration terms are small. The atmospheric boundary layer over sea-ice is rather complicated,

even for relatively small fractional covers (about four-tenths or more). The surface wind stress, and the near surface wind field, averaged over a region depends not only on the external conditions of the PBL, but also sensitively on the details of the distribution and structure of the sea ice, the buoyancy flux associated with leads and polynas, and height of the shallow inversions often characterizing Arctic boundary layer.

Overland (1985) has reviewed a large body of published data on the atmospheric boundary layer structure over a wide range of ice conditions, and summarized the surface drag regimes in terms of rather broad surface roughness and stability categories. In terms of the effective 10 m drag coefficient,

$$C_d = U/U_{10}$$

where U is friction velocity, and U_{10} is the 10-metre wind speed, Overland estimates $10^3 C_d$ in the range 1.3 to 1.5 for smooth ice, rising to about 2.2 for small ice concentrations in the marginal ice zone (MIZ), 2.5 to 3.0 in nearly continuous pack ice, and as high as 3.0 to 3.7 in the unstable boundary layer over the MIZ. Much lower drag coefficients however characterize the winter arctic boundary layer in low inversion conditions.

To specify surface winds from the pressure field over sea ice, we require knowledge of the geostrophic wind ratio U_{10}/G and the turning angle α between U_{10} and G , Overland (1985) has used a second-order closure model of the inversion capped boundary layer to calculate these quantities as functions of $Z_i = U/fZ_1$, where f is the Coriolis parameter and Z_1 is the inversion height. Only rough estimates of Z_i and C_d are possible on a synoptic basis, and using Overland's model we have adopted the following categories to specify U_{10}/G and α :

MIZ, smooth ice,	$Z_i \sim 10$,	$10^3 C_d \sim 1.5$,	$U_{10}/G \sim 0.7$,	$\alpha \sim 20^\circ$
MIZ, rough ice,	$Z_i \sim 15$,	$10^3 C_d \sim 2.5$,	$U_{10}/G \sim 0.65$,	$\alpha \sim 25^\circ$
Arctic winter,	$Z_i \sim 30$,	$10^3 C_d \sim 2.5-3.0$,	$U_{10}/G \sim 0.55$,	$\alpha \sim 45^\circ$

Even for the relatively crude categories given above, specification of the most

appropriate category for each grid point will be difficult because of the limitations of existing ice-cover analyses, and the difficulty of specifying air-sea stability over the open Beaufort Sea from conventional meteorological analysis products. Until these products are improved, the specification of the drag regimes will be quite subjective. However, given the data sparsity of the region, it is likely that the dominant source of error in the specification of surface winds will be errors in the pressure gradient.

KINEMA

Over open-ocean Northern Hemisphere mid-latitude basins, kinematic analysis provides a powerful basis for reduction of systematic errors in marine surface wind fields.

The kinematic wind fields are by far the most accurate and least biased winds, primarily because the method allowed a thorough re-analysis of the evolution of the wind field. Kinematic analysis also allows the wind fields to represent effects not well modelled by pressure-wind transformation techniques, such as temporal variations in surface pressure gradients, and deformation in surface winds near the downstream of coasts. However, the degree of accuracy of such analysis is primarily a function of available observations.

Kinematic analysis is a manual process that involves the following basic steps: (1) assembling and plotting all synoptic observations of wind speed and direction, and sea level pressure, from rigs, ships and land stations at 6-hourly intervals on a suitable base map projection for the storm event of usually 2-4 days duration; (2) identification and rejection of erroneous and unrepresentative observations to the extent possible; (3) construction of a continuity chart which defines the movements of storm centres, fronts and other significant features of the surface wind field; (4) construction of streamlines and isotachs; and (5) gridding of wind speed and direction by hand from the streamline/isotach fields.

Due to limited coverage of marine observations in the Beaufort Sea, the application of the above kinematic analysis for the complete grid is not logical (in terms of costs and accuracy required).

The transformation of wind speed measured at coastal stations to equivalent over-water speed has been studied by Resio and Vincent (1977), Phillips and Irbe (1977) who used data from the Great Lakes, and LaLonde and McCulloch (1975) who analyzed data from the Canadian Beaufort Sea. These empirical studies are quite consistent with each other in demonstrating that the ratio of over-water to over-land wind speed decreases with increasing wind speed and depends also on atmospheric stability (in a form of air-sea temperature difference) and fetch. For light winds over-land, the ratio is in the range of two, but for strong winds and unstable stratification it approaches unity. Resio and Vincent (1977) also demonstrated that the Planetary Boundary Layer model of Cardone (1969) may be used to predict the dependence of the ratio of wind speed and stability, given a specification of the anemometer height and terrain roughness of the measurement site. In general, the model predicts the ratio to depend weakly also on latitude.

A recent study by Kozo and Robe (1986) highlights the influence of the Brooks Mountain Range over the Arctic coastal waters. The orographic effect of these mountains could also be used in the kinematic analysis.

Of course, the above concepts need to be applied in the manual reconstruction of surface streamline-isotach analyses by skilled analysis. Program KINEMA, merely provides the framework for the assimilation of kinematic winds into a background field specified by PRESTO. As presently coded, KINEMA gives full weight to the kinematic winds at grid points entered; i.e. kinematic winds replace pressure-field derived winds, in lieu of partial weighting and blending of pressure-derived and kinematic winds.

The above technique was used in the previous study (for open water conditions). However, as mentioned previously, it was NOT performed in the present hindcast.

2.2.3

Wind specification software description

A detailed user's guide was provided separately. This section provides a very brief description of the wind specification software. The program consists of the following main subroutines:

- GRIDDLE: computes latitude and longitude at grid points
- STEREO: computes rectangular coordinates on stereographic projection of points whose latitude and longitude were computed in GRIDDLE.
- PRESTO_WIND: computes gridded surface wind fields from digitized isobar charts (i.e. provides objective analysis winds)
- KINEMA: replaces objective winds with kinematic analysis winds.

Two preliminary programs (GRIDDLE and STEREO) are to be run once before the first wind run. Of the output files, GRIDDLE.BIN and STEREO.BIN are to be kept standing; all other output are print files that can be deleted after printing.

GRIDDLE computes latitude and longitude at grid points. The wind grid extends from 68° to 76° N at 20 minute intervals, and 162° to 120° W at one degree intervals. The pressure grid extends beyond the above on all four edges, to permit computation of pressure gradients, viz: 66°40' to 77°20'N, 167° to 115°W (see Figure 2 for example). It is important to cover this area when digitizing isobars.

PRESTO_WIND computes surface winds from the digitized isobars. It computes winds over sea (also over land) by executing subroutine CBLFM, which computes friction velocity and surface wind at prescribed reference height (here 10 meters) from geostrophic wind, air-sea temperature difference, air temperature, and temperature gradient. CBLFM is documented in Cardone et al. (1978). Winds over ice are computed in subroutine CBLICE, which takes the geostrophic wind and applies a scale factor and a counterclockwise (in northern hemisphere) rotation based on the work of Overland (1985);

<u>Drag Code</u>	<u>Ice cover</u>	<u>Scale factor</u>	<u>Rotation</u>
2	MIZ, smooth ice	70%	20 degrees
3	MIZ, rough ice	65%	25 degrees
4	Arctic winter	55%	45 degrees

Program PRESTO_WIND makes four output files:

1. File 50: Wind speed and direction on the whole grid. Wind direction, from which wind is blowing, in degrees true. Wind speed in m/s (represents 10 m reference level, effective neutral wind).
2. File 51: U and V components of wind and the fourth power of wind speed on the whole grid. This file can be deleted as soon as either program KINEMA has been run, or it is decided that no kinematic overlay is wanted.
3. File 52: maximum wind speed (m/s) and its grid point location each 6 hours.
4. File 53: Wind speed and direction at six preselected grid points for quick check of model results.

Program KINEMA accepts wind speeds and directions on that part of the grid from 152° W to 120° W and 68° N to 76° N, or any subset thereof.

The output files 50, 52, 53 from KINEMA have the same size, format, and contents as the files of the same names from PRESTO_WIND.

The above software is written in FORTRAN and was compiled on a P.C. (e.g. a COMPAQ 386 or compatibles) using LAHEY FORTRAN-77 32-bit compiler.

3.0

HINDCAST PRODUCTION

Ten winter storms were selected by the Scientific Authority. The storms were selected based on their severity index (defined as the product of maximum wind speed during the storm times number of hours that the wind is greater than or equal to 34 kts). These ten storms are listed below:

Table 1 WINTER STORMS

Storm	Year	Start	End	Duration	No. obs.	max. wind.	severity
1	1974	Jan.6	Jan.10	99	55	59	5841
2	1982	Feb.6	Feb.8	55	55	52	2860
3	1972	Feb.17	Feb.19	36	36	50	1800
4	1982	Feb.12	Feb.13	20	20	50	1000
5	1978	Feb.7	Feb.7	14	14	52	728
6	1974	Jan.28	Jan.29	12	12	59	708
7	1974	Apr.13	Apr. 13	14	14	50	700
8	1962	Jan.21	Jan.21	6	6	56	336
9	1961	Apr.21	Apr.21	6	6	52	312
10	1957	Jan.15	Jan.16	5	5	57	285

In addition four summer (open-water) season storms were selected (pre 1976 period) as follows:

Table 2 SUMMER STORMS

Storm	Year	Start	End	Duration	No. obs.	max. wind.	severity
11	1973	July 21	July 21	1	1	48	48
12	1972	Aug. 20	Aug. 20	1	1	50	50
13	1970	Sept. 13	Sept. 15	45	45	65	2925
14	1962	Sept. 27	Sept. 27	3	3	57	171

3.1

WIND FIELDS PRODUCTION

For each storm, the AWC or CMC synoptic pressure charts were used as base maps. The pressure fields were reanalyzed and digitized as described in Section 2. The following table lists the 14 storm durations (year-month-day-hour in GMT), and the ice conditions used in the hindcast. For the summer storms, actual ice charts were used to define the open water area.

STORM	# CHARTS	FROM/TO	ICE CONDITION
1	21	74-01-06-00/11-00	Smooth ice
2	13	82-02-06-00/09-00	Smooth ice
3	13	72-02-17-00/20-00	Smooth ice
4	9	82-02-12-00/14-00	Arctic winter
5	11	78-02-06-00/08-12	Rough ice (unstable)
6	9	74-01-28-00/30-00	Arctic winter
7	11	74-04-12-00/14-12	Arctic winter
8	9	62-01-20-00/22-00	Arctic winter 1st half/rough 2nd 5/4
9	11	61-04-20-00/22-12	Arctic winter
10	8	57-01-15-00/16-18	Rough (unstable)
11	11	73-07-20-00/22-12	Rough ice + open water
12	9	72-08-19-12/21-12	Rough ice + open water
13	13	70-09-13-00/16-00	Arctic winter (unstable) + open water
14	11	62-09-26-00/28-12	Rough Ice + open water

The results from the model runs were stored on diskettes and delivered to the Scientific Authority. Appendix A shows selected plots of the wind field near the peak of each storm.

DISCUSSION

The output from the hindcast analyse overall is very good. An accurate pattern is displayed in the output from most of the time periods. Seven out of the 14 storms were found to have accurate representation of both wind speed and direction over the entire field throughout the storms' duration. The output of the storms' hindcast were compared to the actual observations available, both land stations and marine observations along the coastline. Where no observations were available, manual measurements of the gradient were conducted. Most of the wind speeds over land were excessive, but this is due to the program treating the entire grid as being covered by water in open water season cases (this is a default in the program). In storm number 2 (Figure 3), easterly winds along the coast were running about 10 kt too strong. This probably was due to the lack of a friction coefficient over the land rather than any error in the hindcast analysis or the program measurement of the gradient. (It should be noticed that in the current program, the land is treated as water and winds outside the Beaufort Sea boundaries should be ignored).

Three of the storms produced westerly winds along the coast that were too light. This of course is due to the channelling effect along the Brooks Range of mountains parallel to the coastline in northern Alaska. This channelling effect produces stronger winds than what would normally be generated by a given gradient. The actual winds along the coast in storm number 1 (Figure 4) were 5-10 kts stronger than the model output. The output in storm number 7 (Figure 5) had maximum values along the coast of 10-15 kt. There were though observations of up to 25 kt from some of the sites. Storm number 13 had the greatest error in this westerly wind regime. The model output gave 15-20 kt winds where 40-50 kt winds were being observed (Figure 6). The effect of the mountain range is very complex and can only be treated, at current state of knowledge, subjectively. This would require kinematic analysis which was not applied in the present study. This subject requires extensive research work which was beyond the scope of this study.

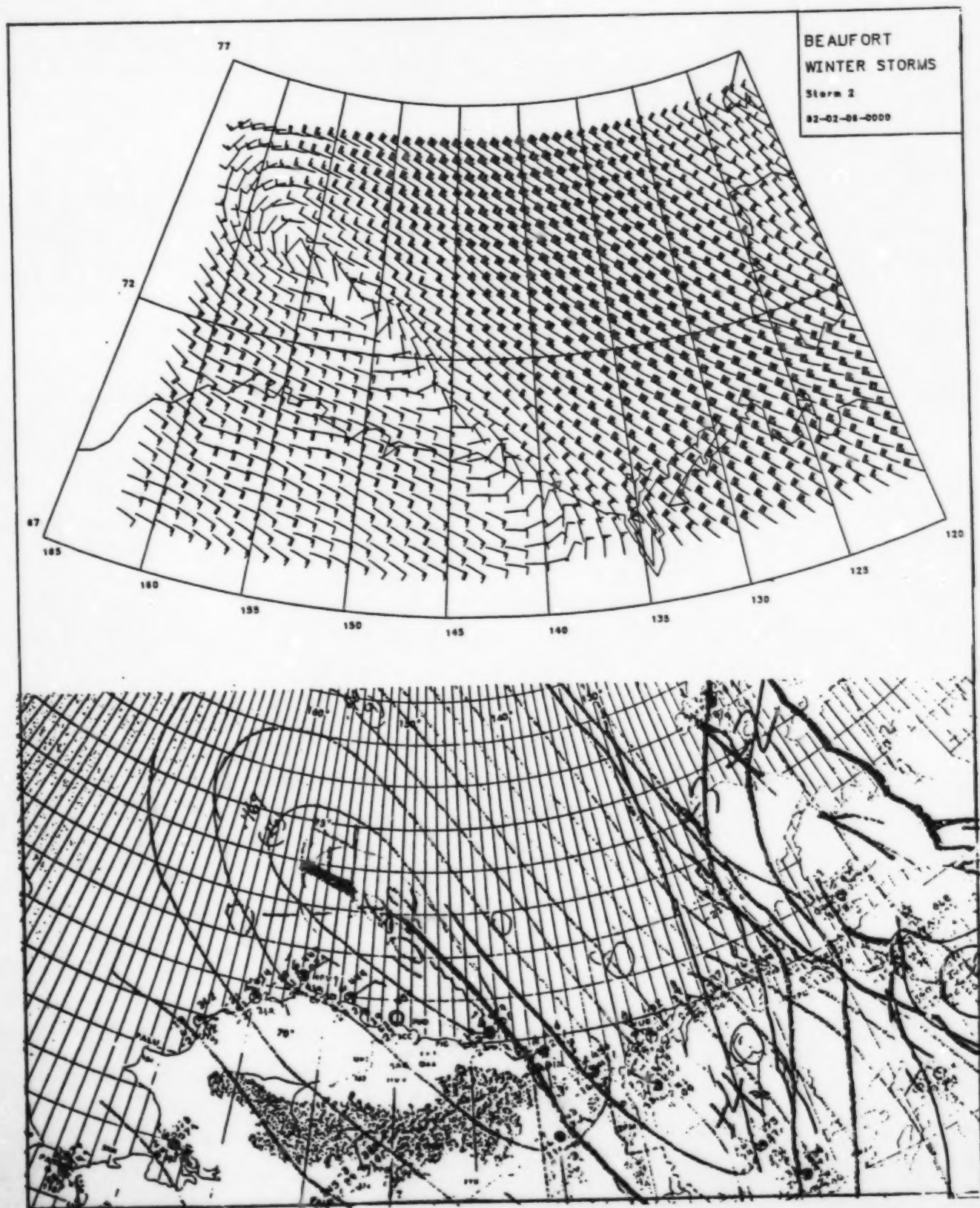
The largest discrepancy in the wind direction appears to be due to the

presence of fronts or high pressure ridges. The winds from the model output, in the vicinity of a front or a ridge, do not take the nearly parallel form to the axis of the front or ridge that usually occurs. A good example of this is storm #11 (Figure 7) where a ridge axis lies west to east just inland from the Alaska Beaufort coastline. The winds along the coast are westerly keeping parallel to the ridge axis. Model output winds in the same area are already veering, staying more parallel to the isobars rather than the ridge axis. One way possibly to correct this problem would be to over-emphasize a trough, in the case of a front, or a ridge of high pressure during the isobaric analysis. This may then force a wind direction closer to that of the actual observed wind direction. The other way of course is to use the kinematic analysis technique described in Section 2.0, provided a good coverage of wind observations is available.

An additional 20 severe Beaufort Sea storms have been hindcast for the open water season between 1977 and 1985 however they are not part of this report. Dates are listed below. Because there were sufficient marine observations, kinematic analysis was performed on these storms. For further information the reader is referred to Agnew et al. (1989).

Additional Beaufort Sea Storm Dates

- | | |
|---------------------------------|---------------------------------|
| 1. Aug 25, 1977 - Aug 28, 1977 | 11. Aug 30, 1980 - Sep 04, 1980 |
| 2. Sep 23, 1977 - Sep 26, 1977 | 12. Aug 01, 1981 - Aug 04, 1981 |
| 3. Oct 06, 1977 - Oct 13, 1977 | 13. Aug 16, 1981 - Aug 18, 1981 |
| 4. Aug 30, 1978 - Sep 04, 1978 | 14. Aug 30, 1981 - Sep 02, 1981 |
| 5. Sep 28, 1978 - Oct 02, 1978 | 15. Sep 27, 1981 - Sep 29, 1981 |
| 6. Oct 06, 1978 - Oct 10, 1978 | 16. Jul 26, 1982 - Jul 28, 1982 |
| 7. Aug 22, 1979 - Aug 25, 1979 | 17. Sep 20, 1982 - Sep 22, 1982 |
| 8. Sep 29, 1979 - Oct 06, 1979 | 18. Oct 19, 1982 - Oct 22, 1982 |
| 9. Oct 23, 1979 - Oct 26, 1979 | 19. Nov 07, 1983 - Nov 10, 1983 |
| 10. Aug 28, 1980 - Aug 30, 1980 | 20. Sep 16, 1985 - Sep 19, 1985 |



BEAUFORT
WINTER STORMS

Storm 1

74-01-06-0600

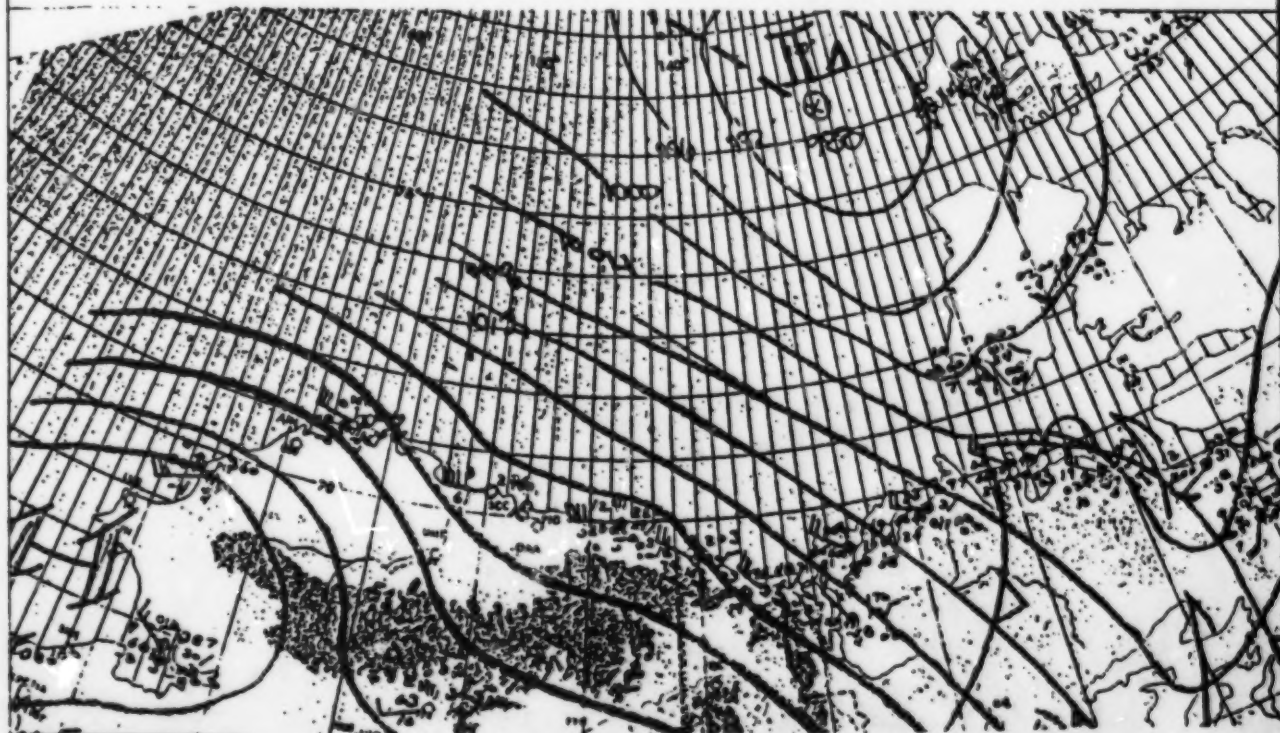
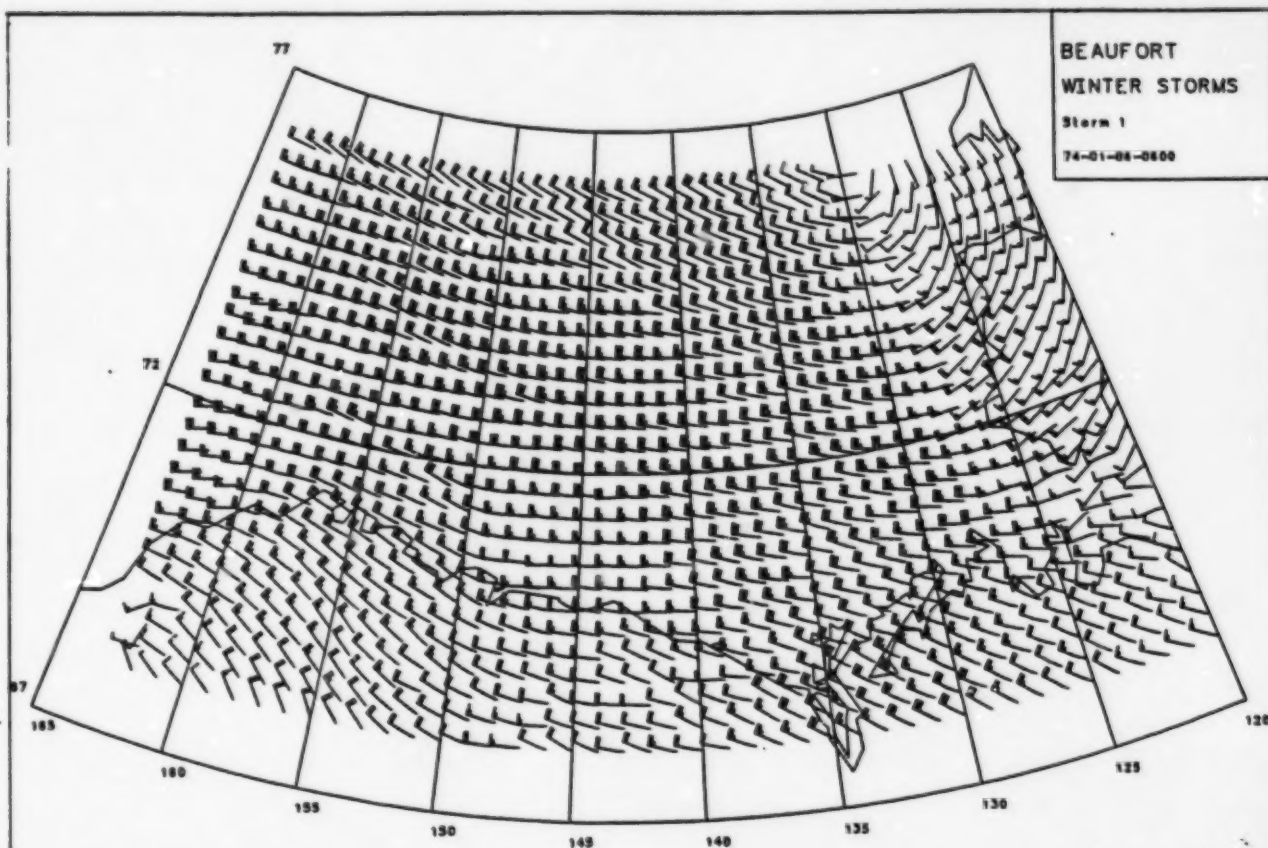


Figure 4

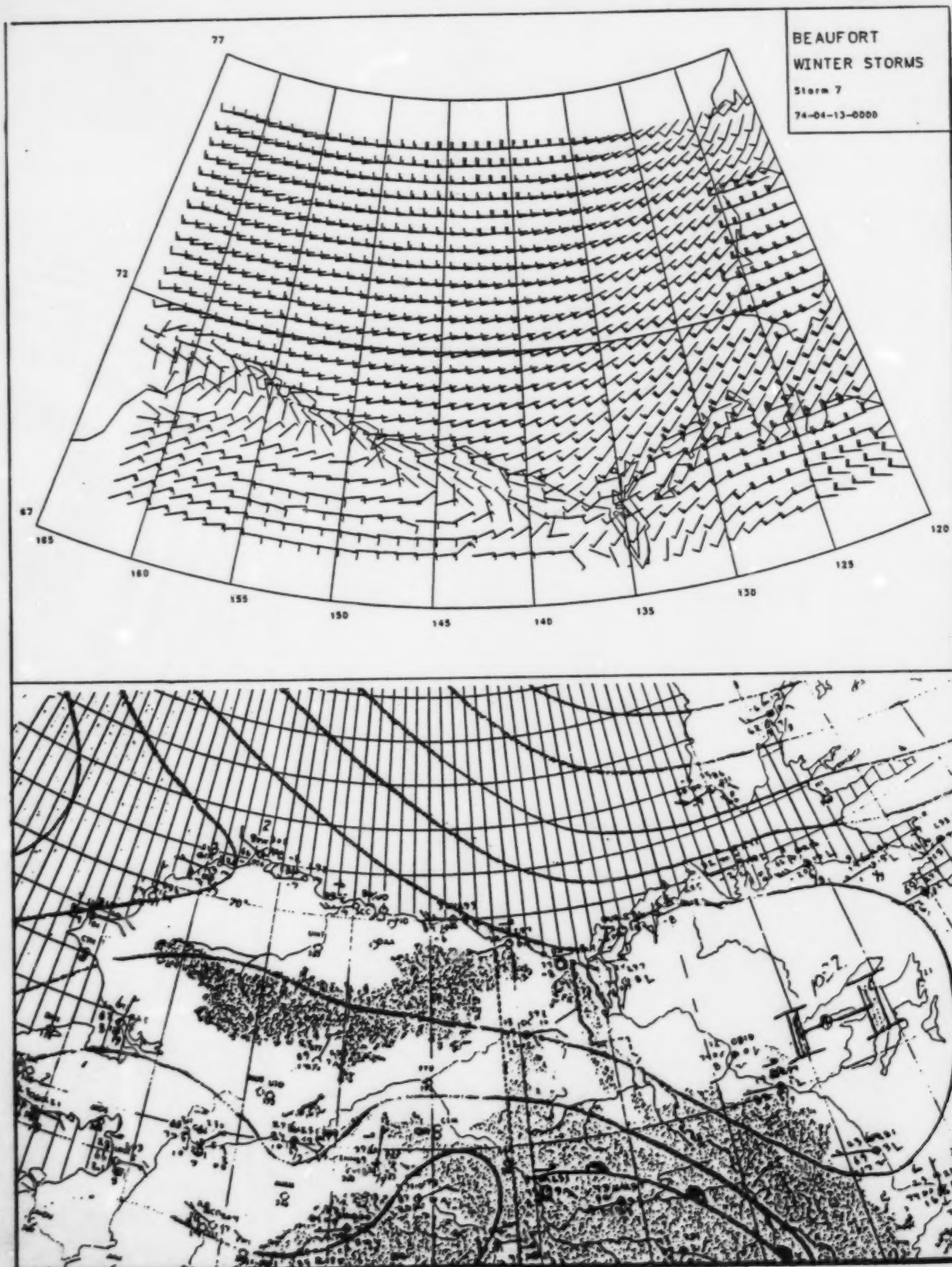


Figure 5

BEAUFORT
WINTER STORMS

Storm 13

78-09-14-0000

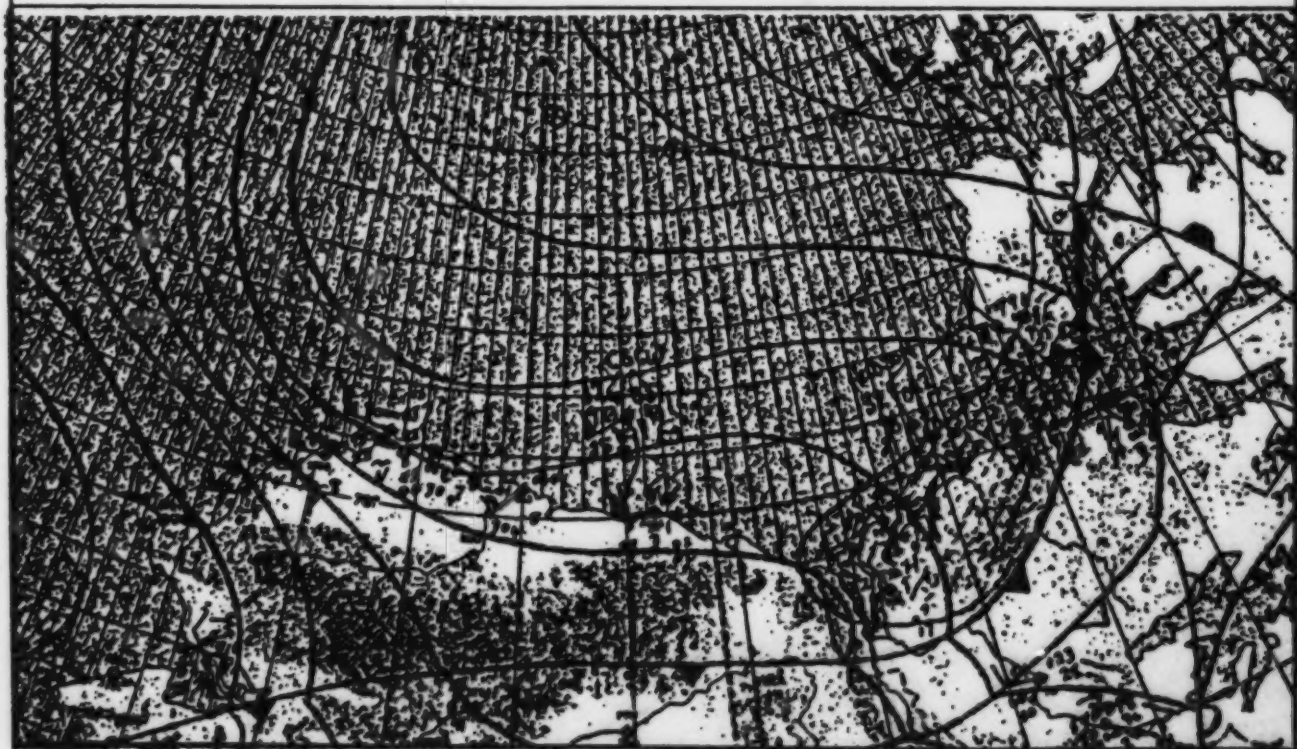
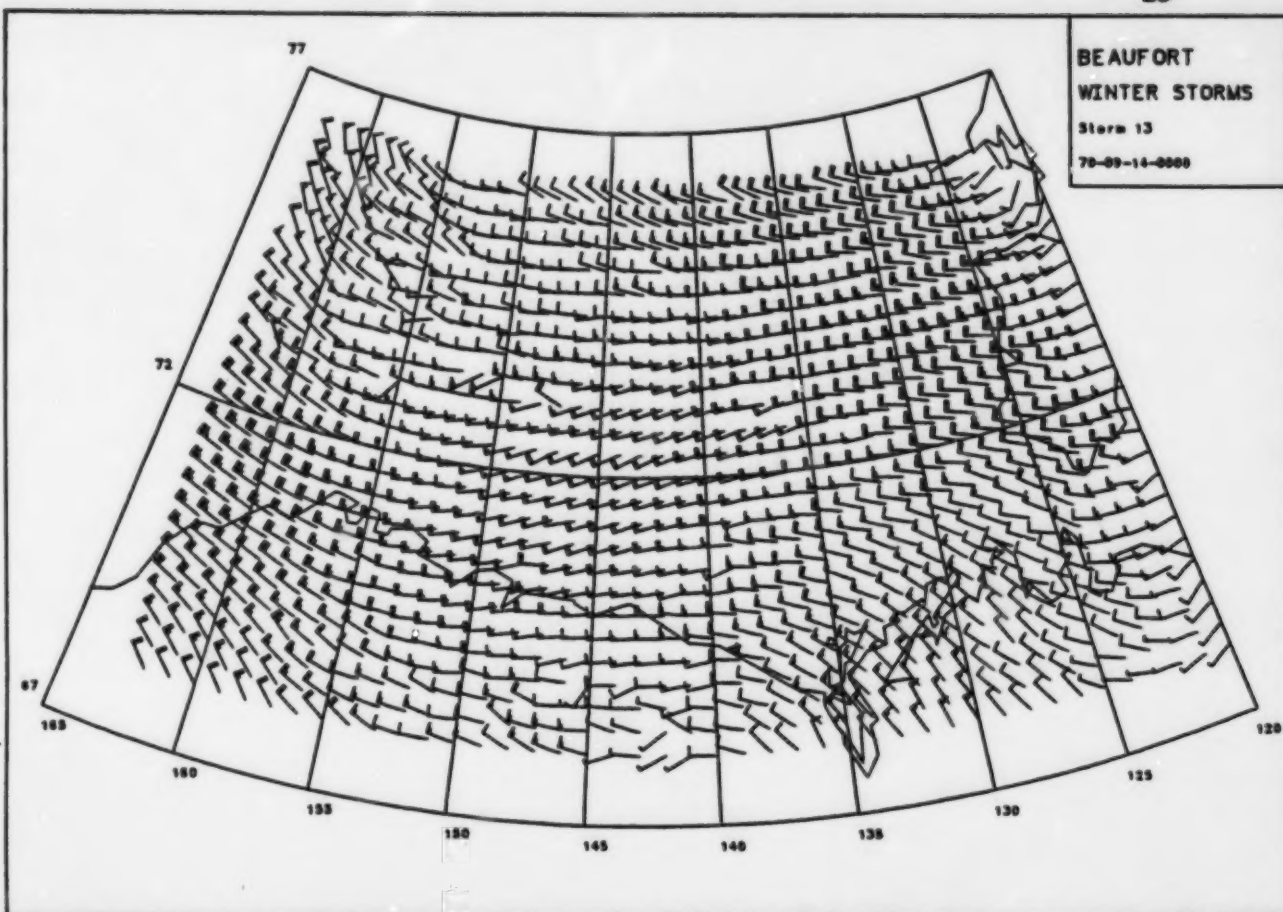


Figure 8

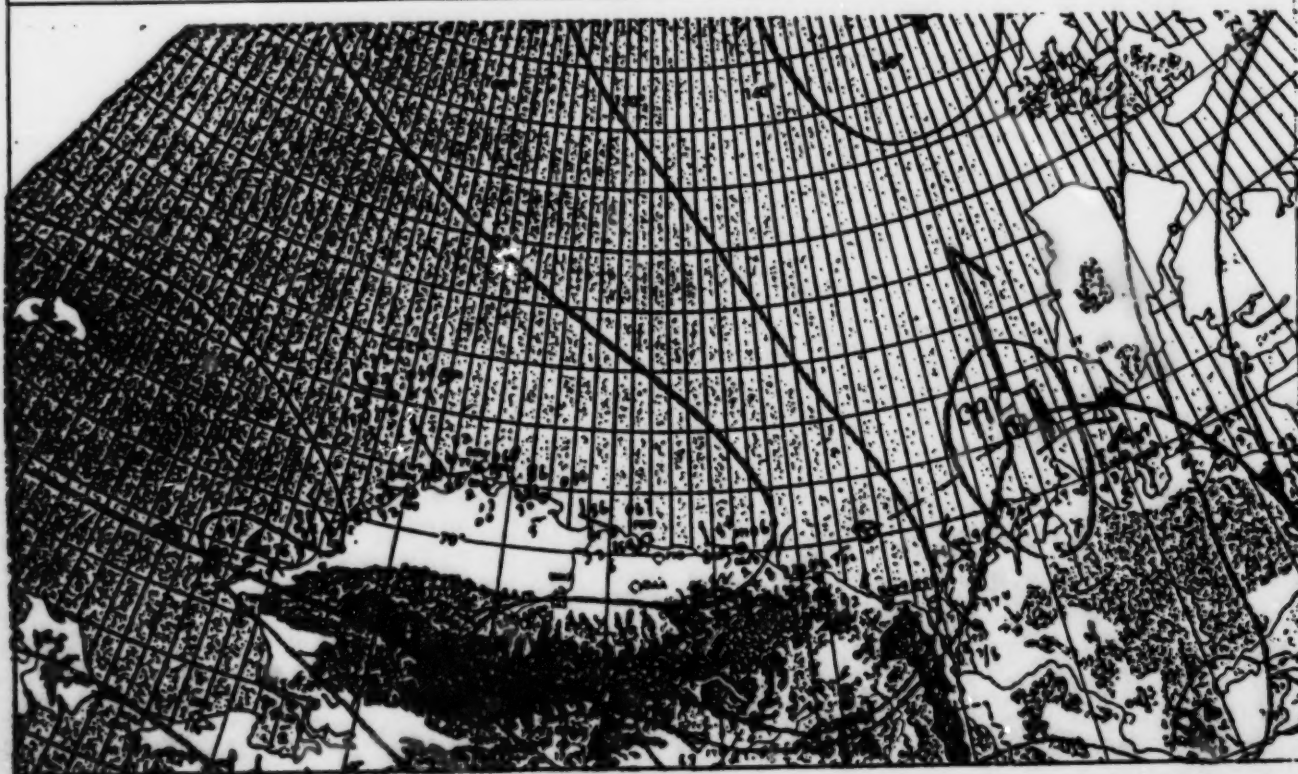
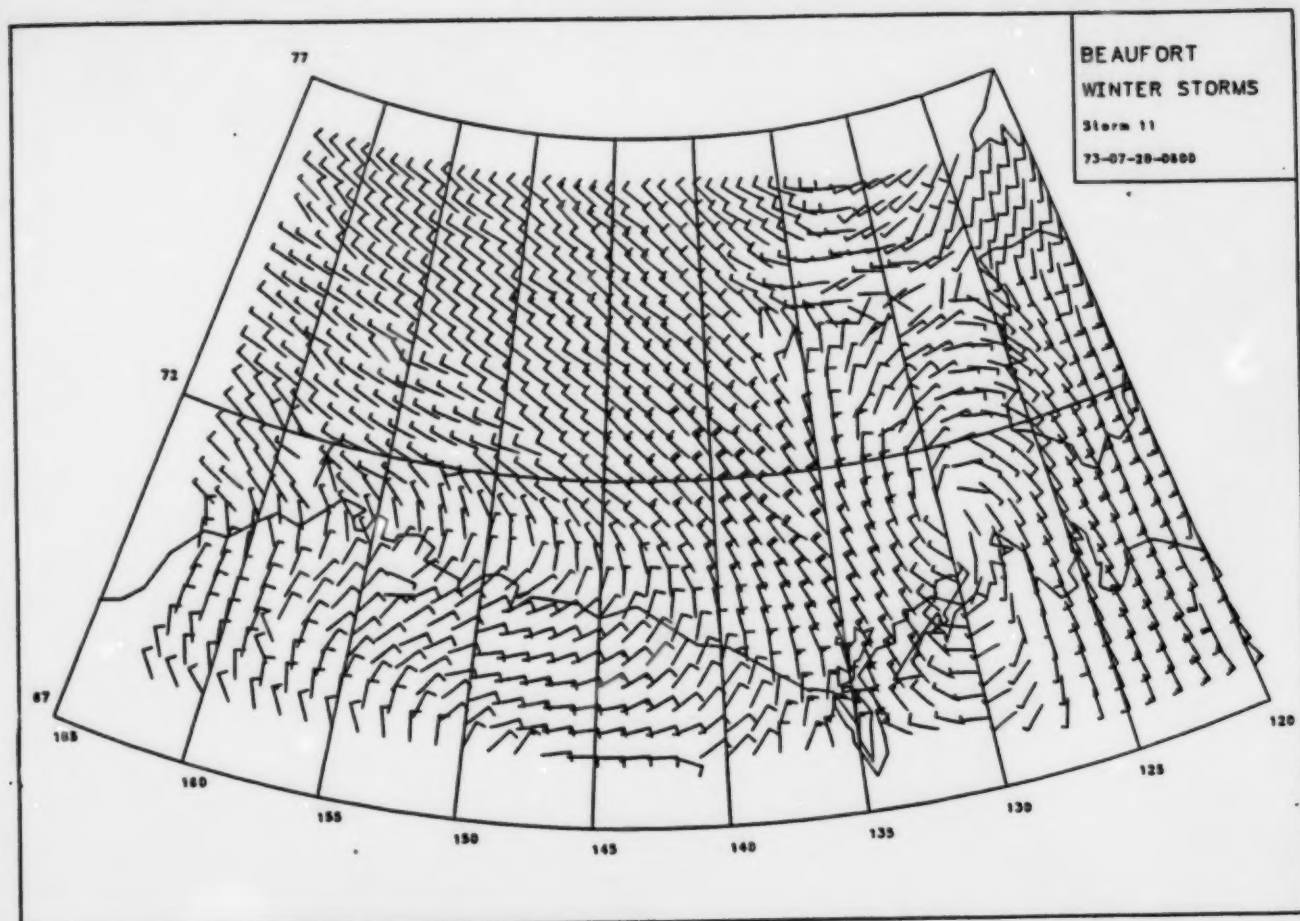


Figure 7

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APPENDIX

STORM # 1

BEAUFORT
WINTER STORMS

Storm 1

74-01-06-0600

77

72

67

165

160

155

150

145

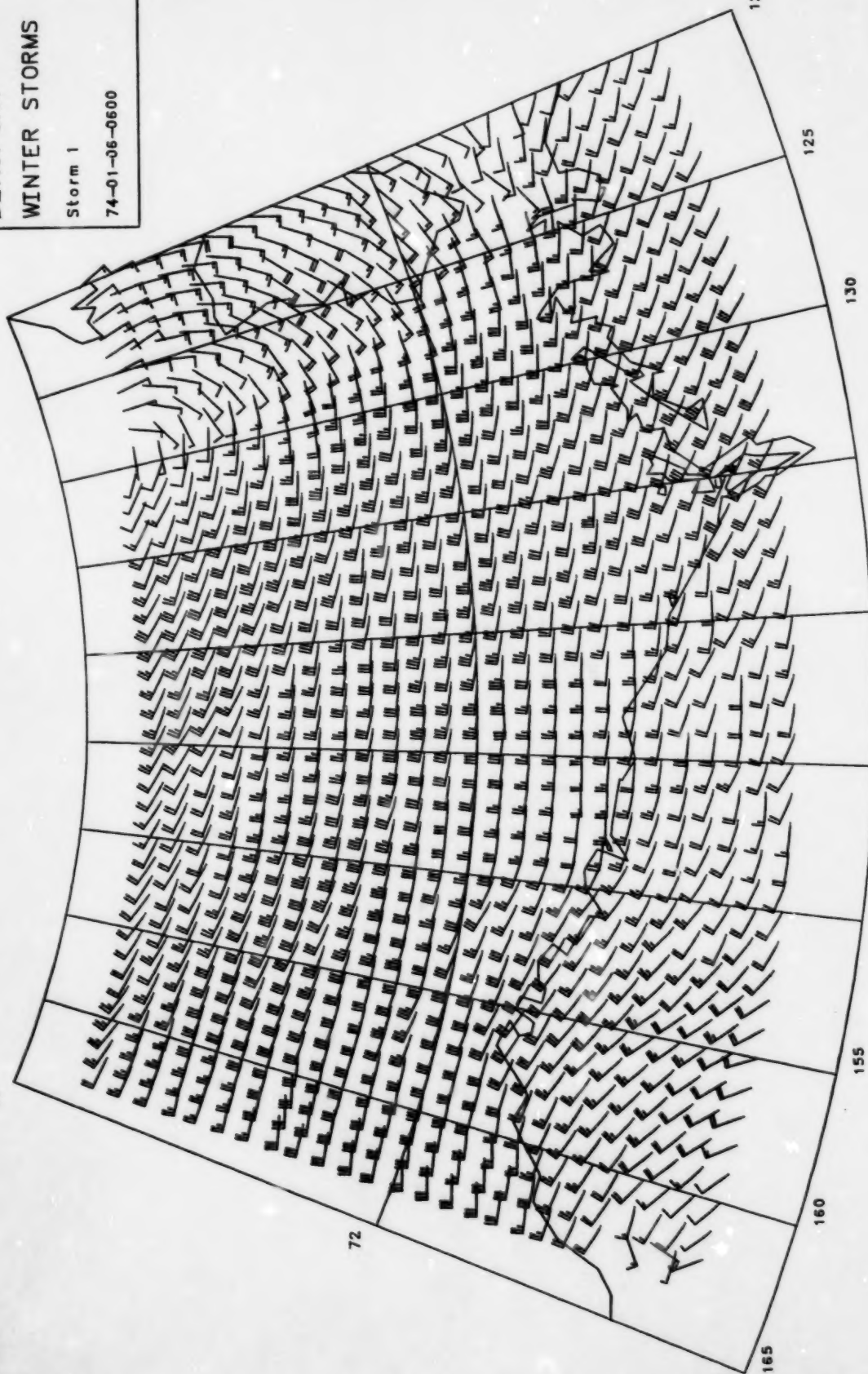
140

135

130

125

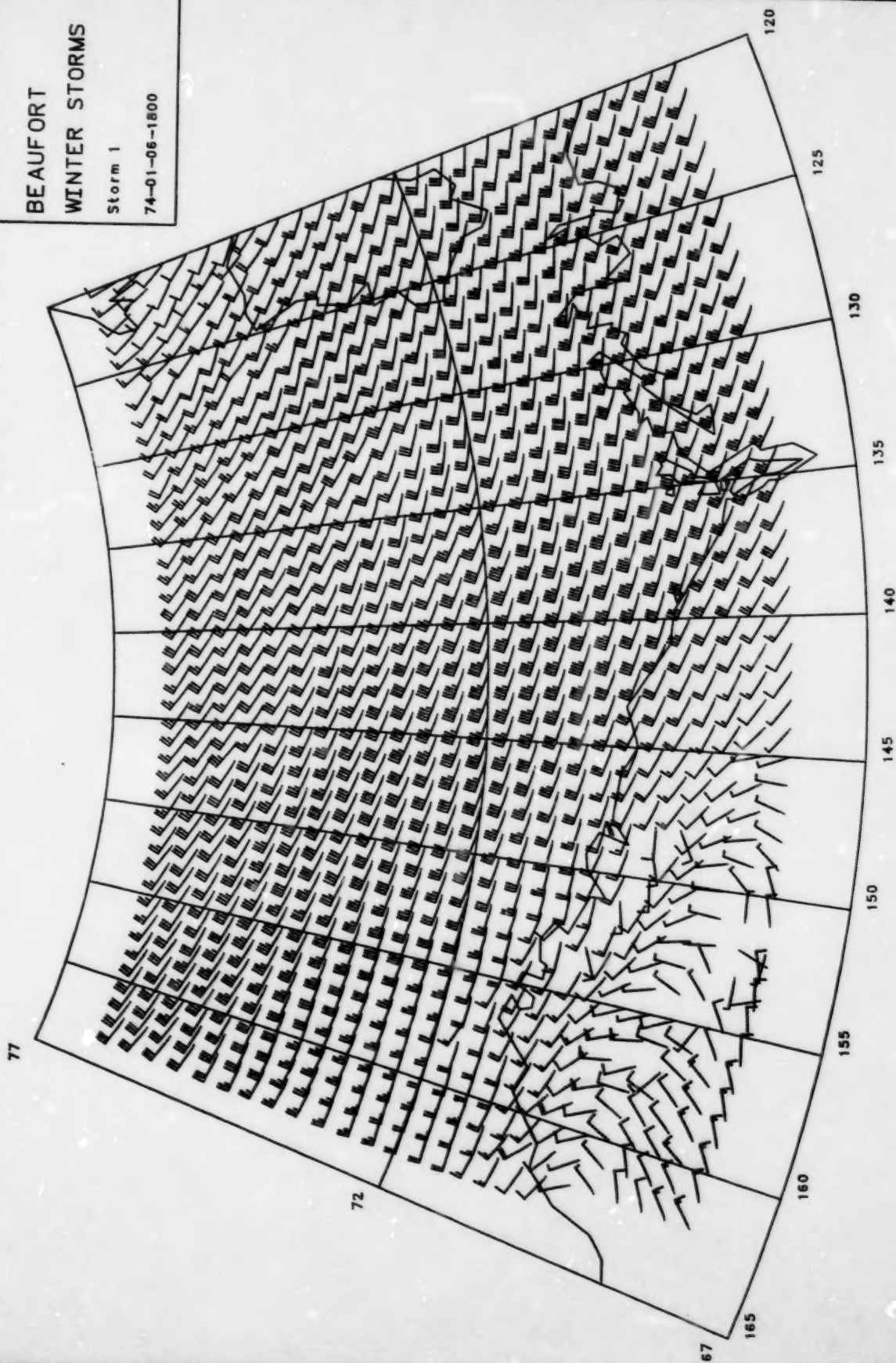
120



BEAUFORT
WINTER STORMS

Storm 1

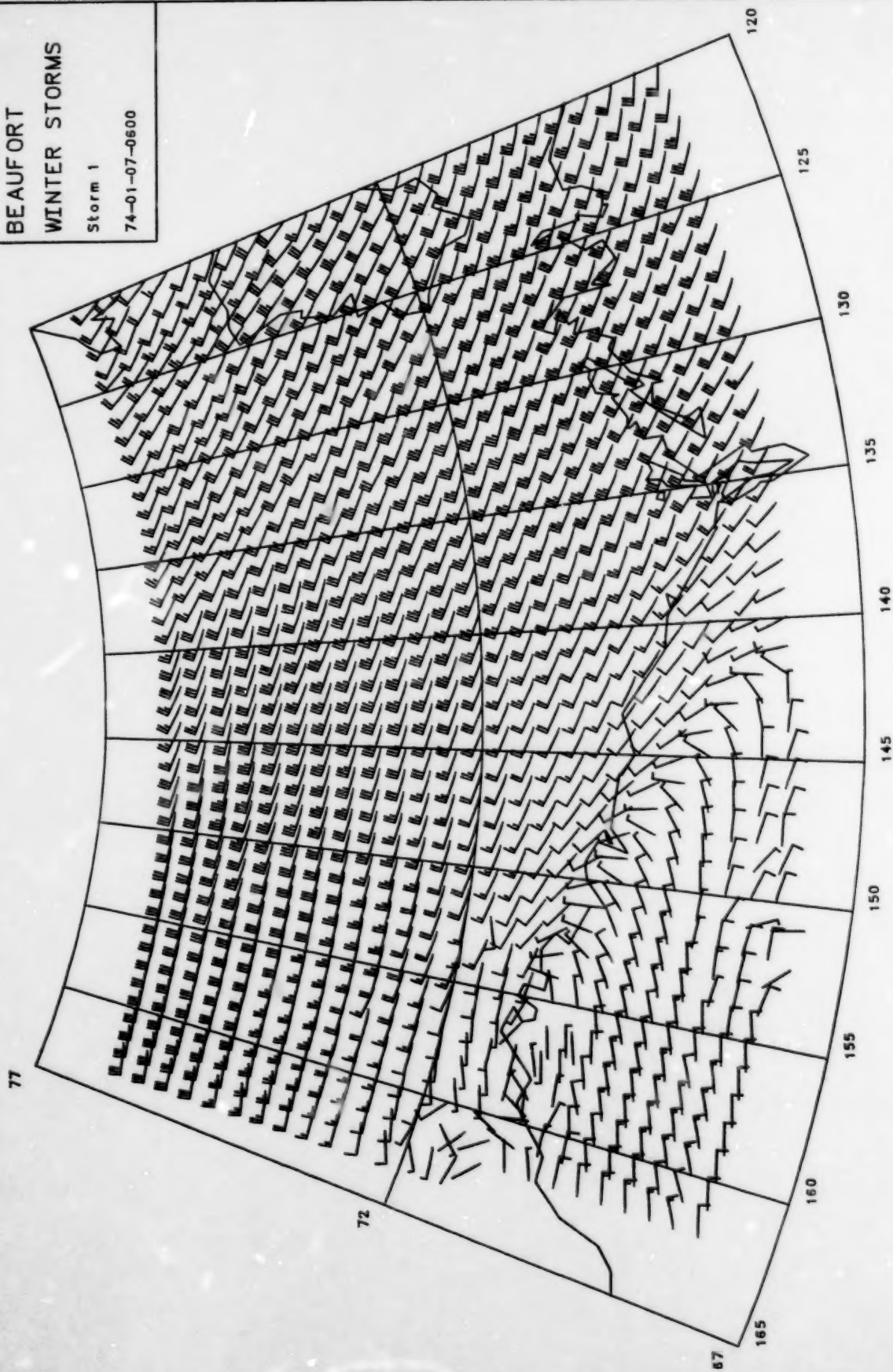
74-01-06-1800



BEAUFORT
WINTER STORMS

Storm 1

74-01-07-0600



STORM # 2

BEAUFORT

WINTER STORMS

Storm 2

82-02-06-0000

77

72

67

165

160

155

150

145

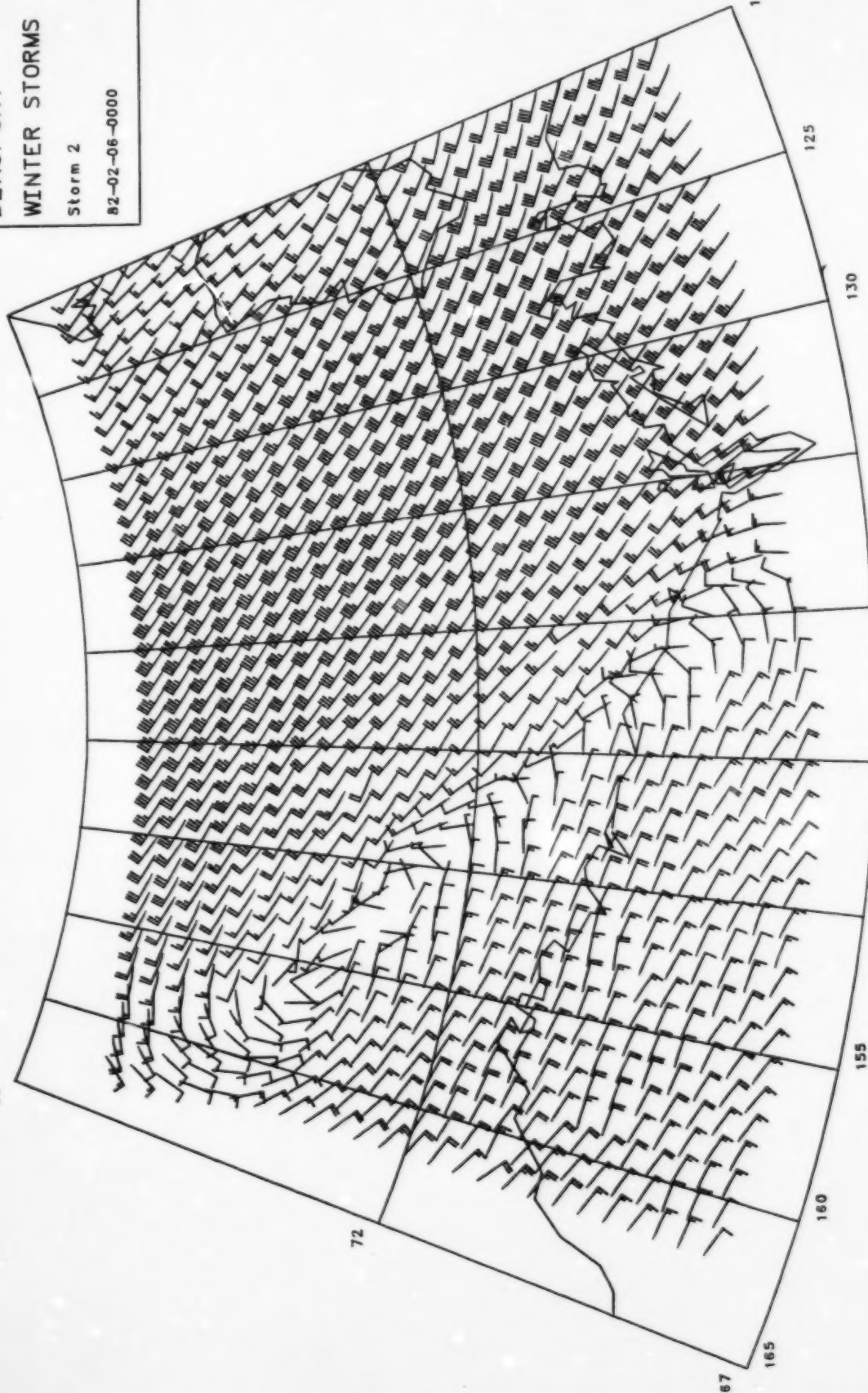
140

135

130

125

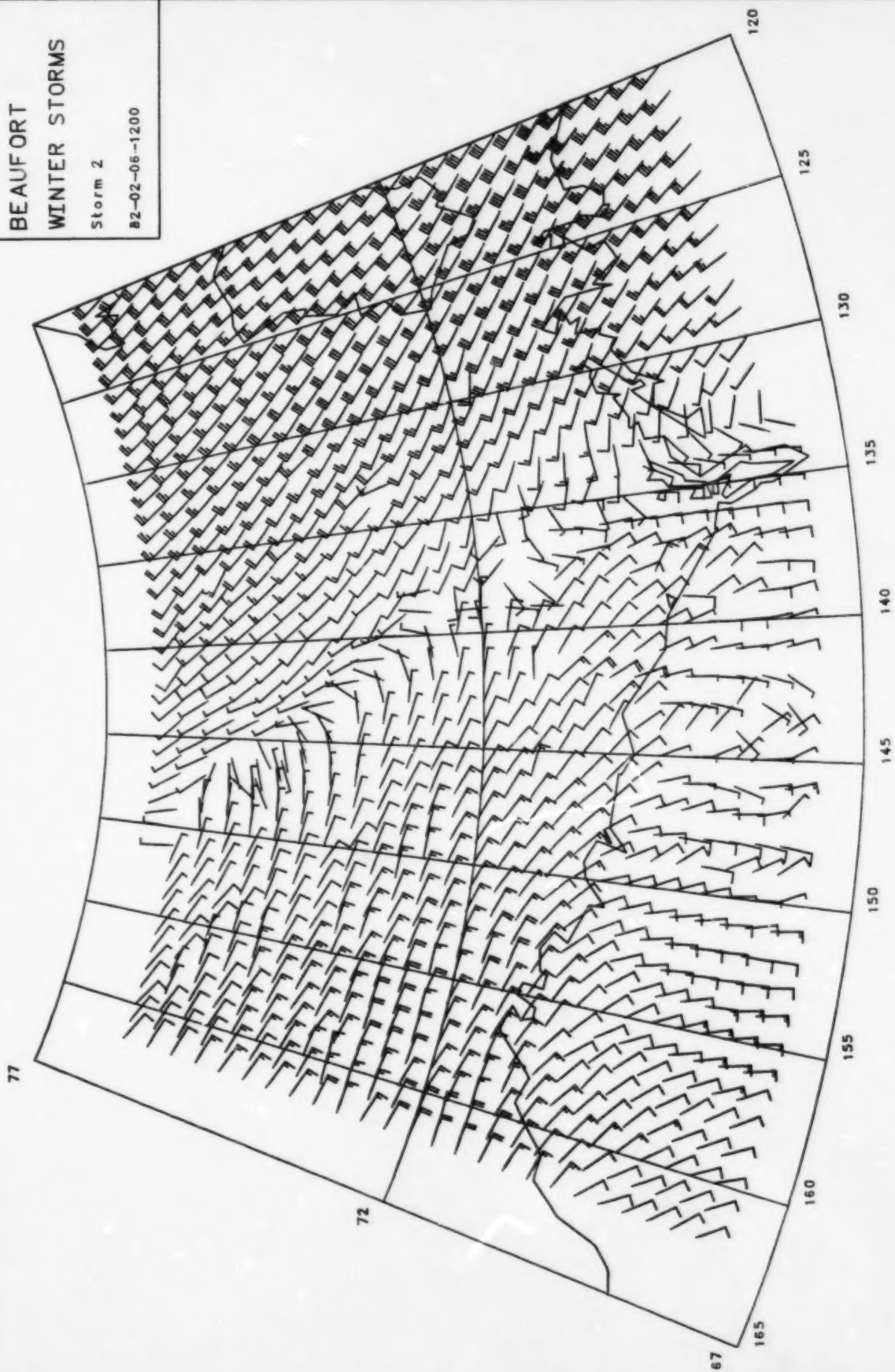
120



BEAUFORT
WINTER STORMS

Storm 2

82-02-06-1200

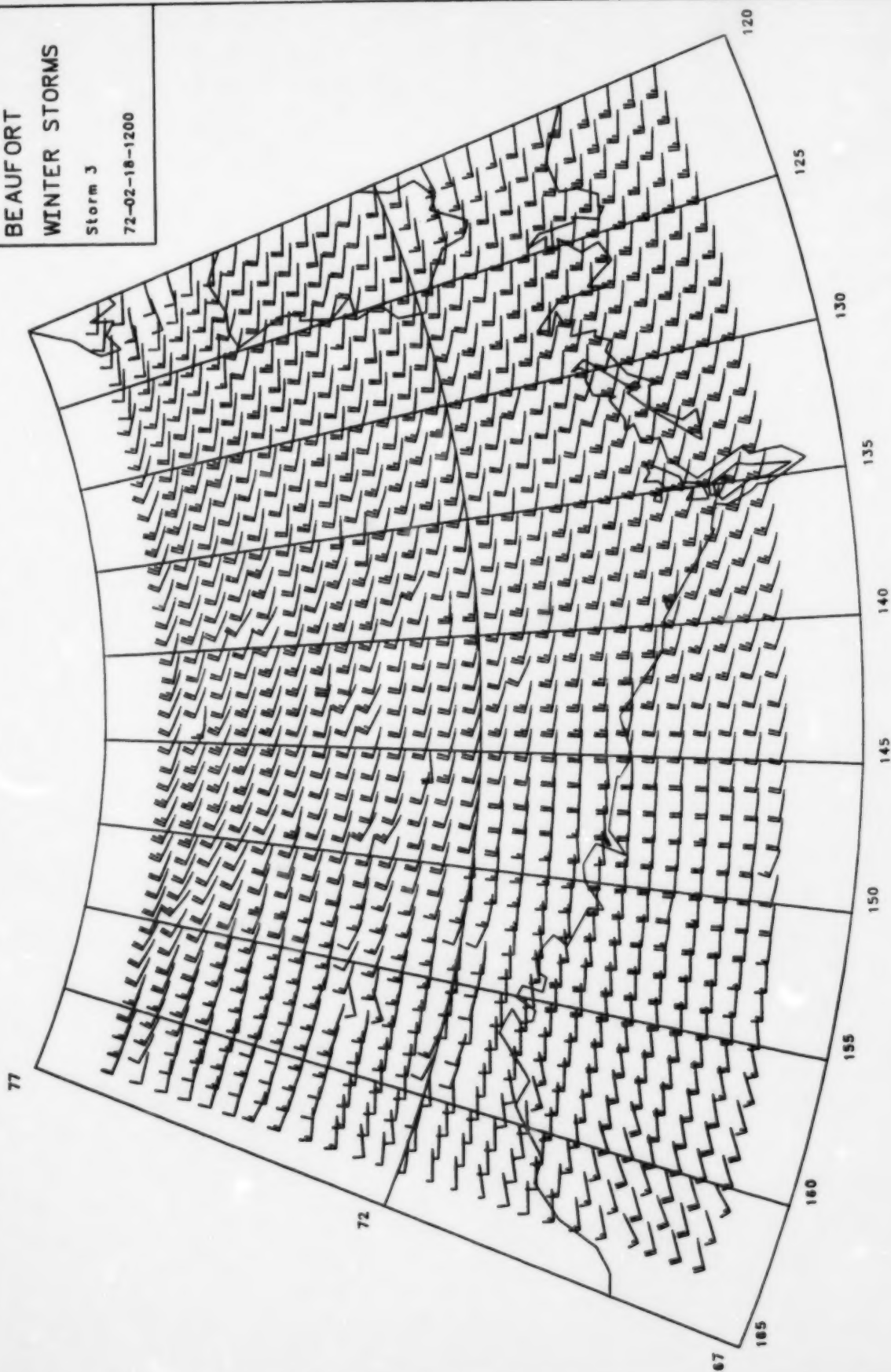


STORM # 3

BEAUFORT
WINTER STORMS

Storm 3

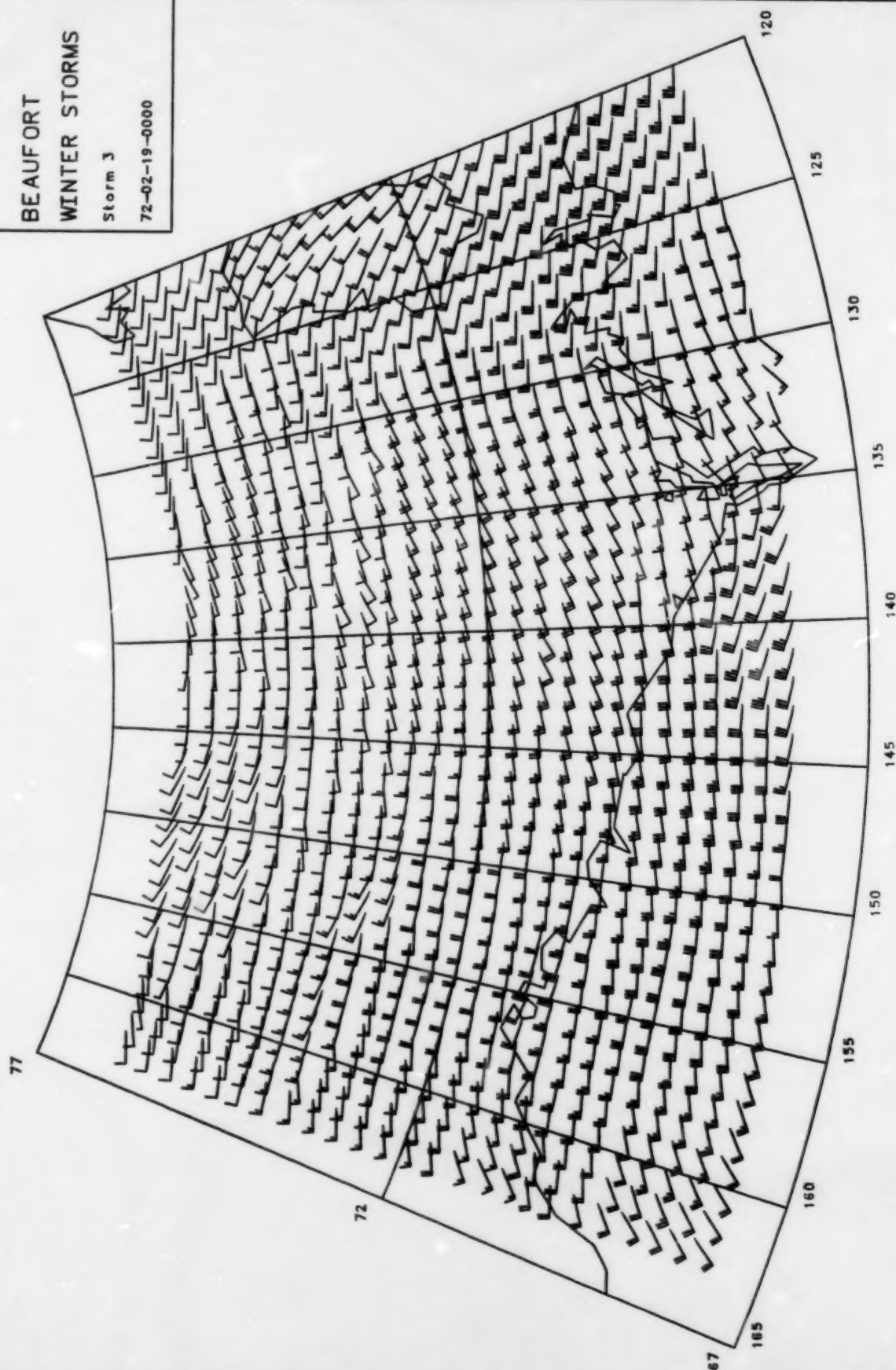
72-02-18-1200



BEAUFORT
WINTER STORMS

Storm 3

72-02-19-0000

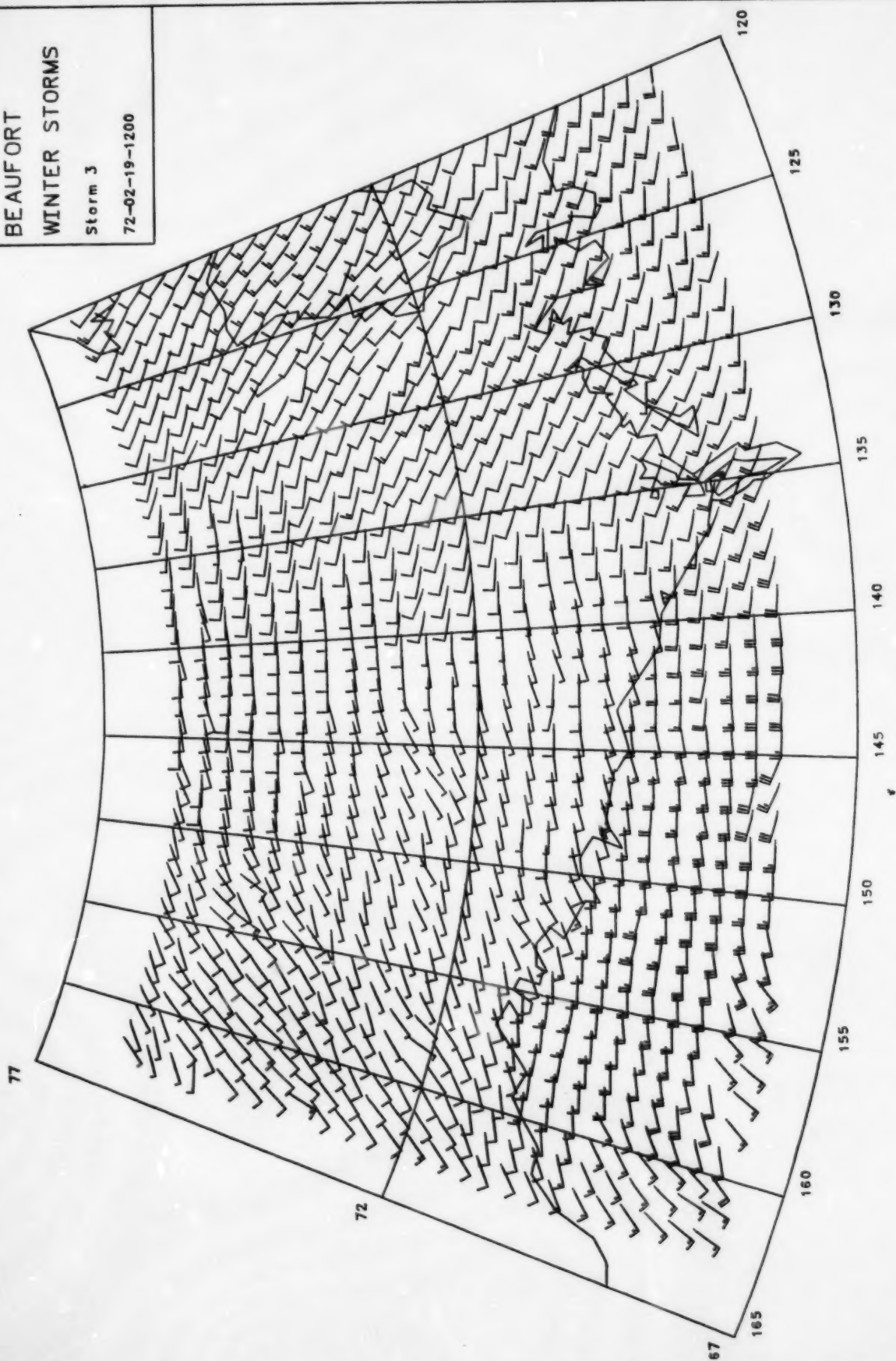


BEAUFORT

WINTER STORMS

Storm 3

72-02-19-1200

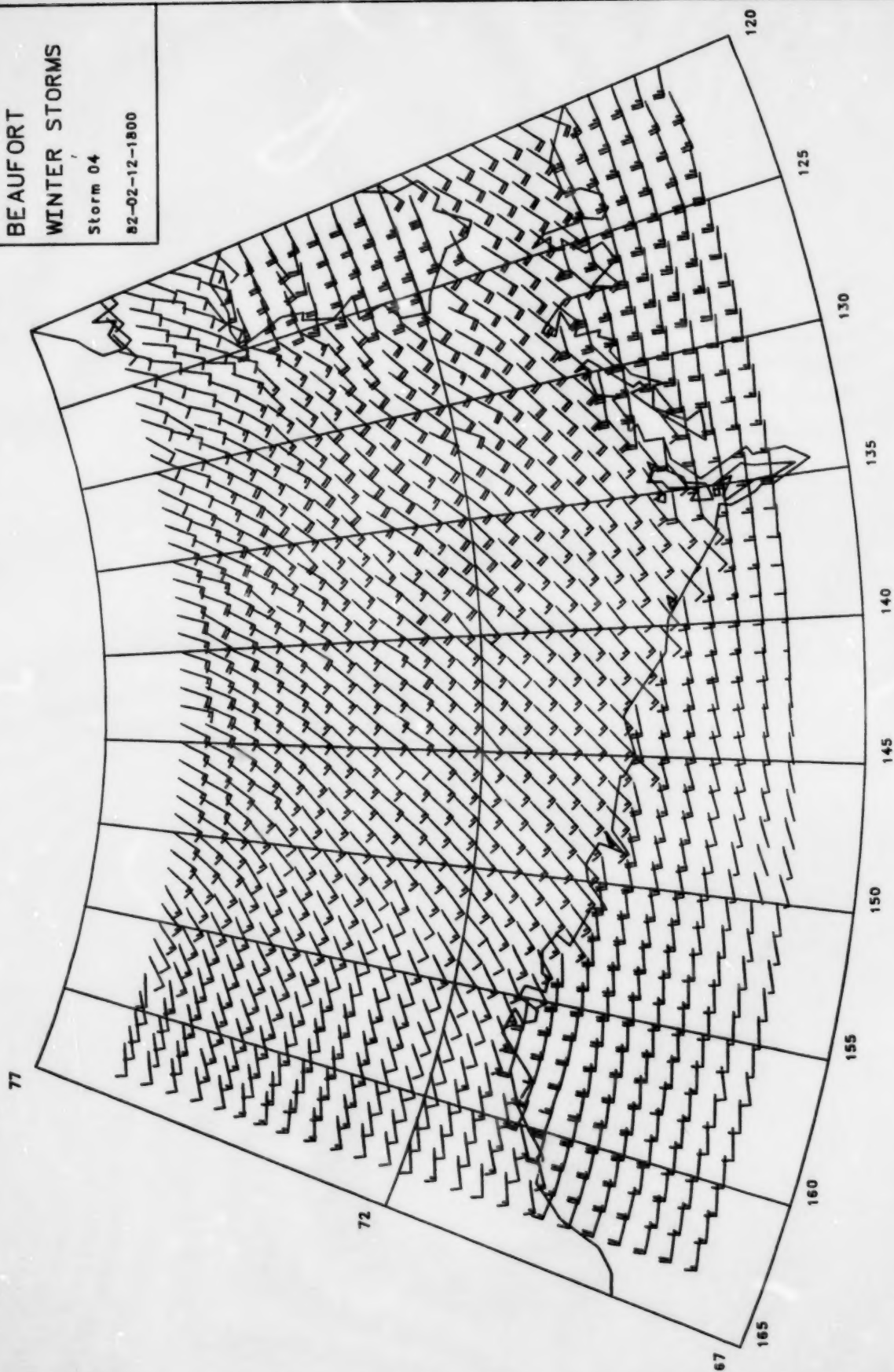


STORM # 4

BEAUFORT
WINTER STORMS

Storm 04

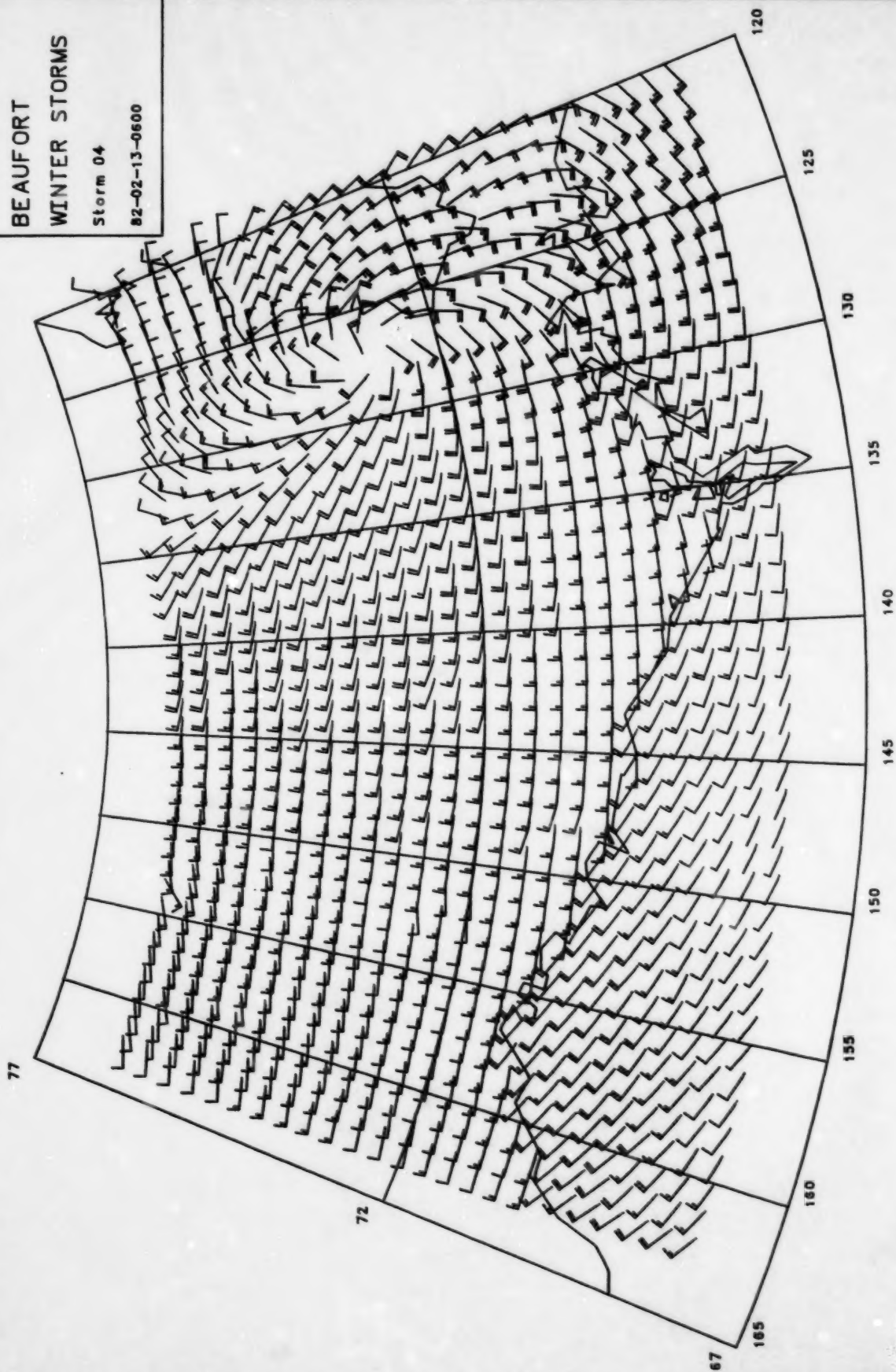
82-02-12-1800



BEAUFORT
WINTER STORMS

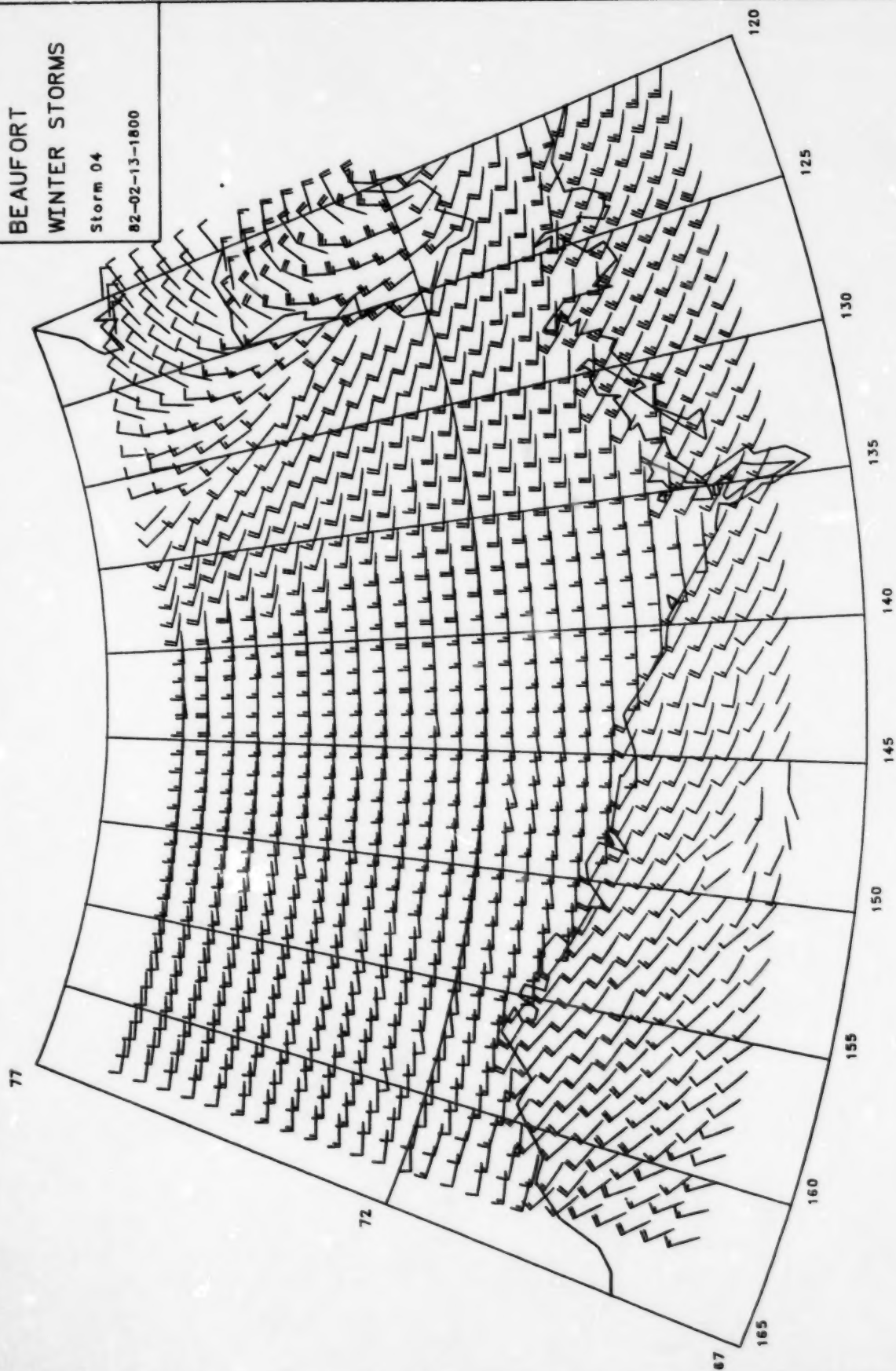
Storm 04

82-02-13-0600



BEAUFORT
WINTER STORMS

Storm 04
82-02-13-1800

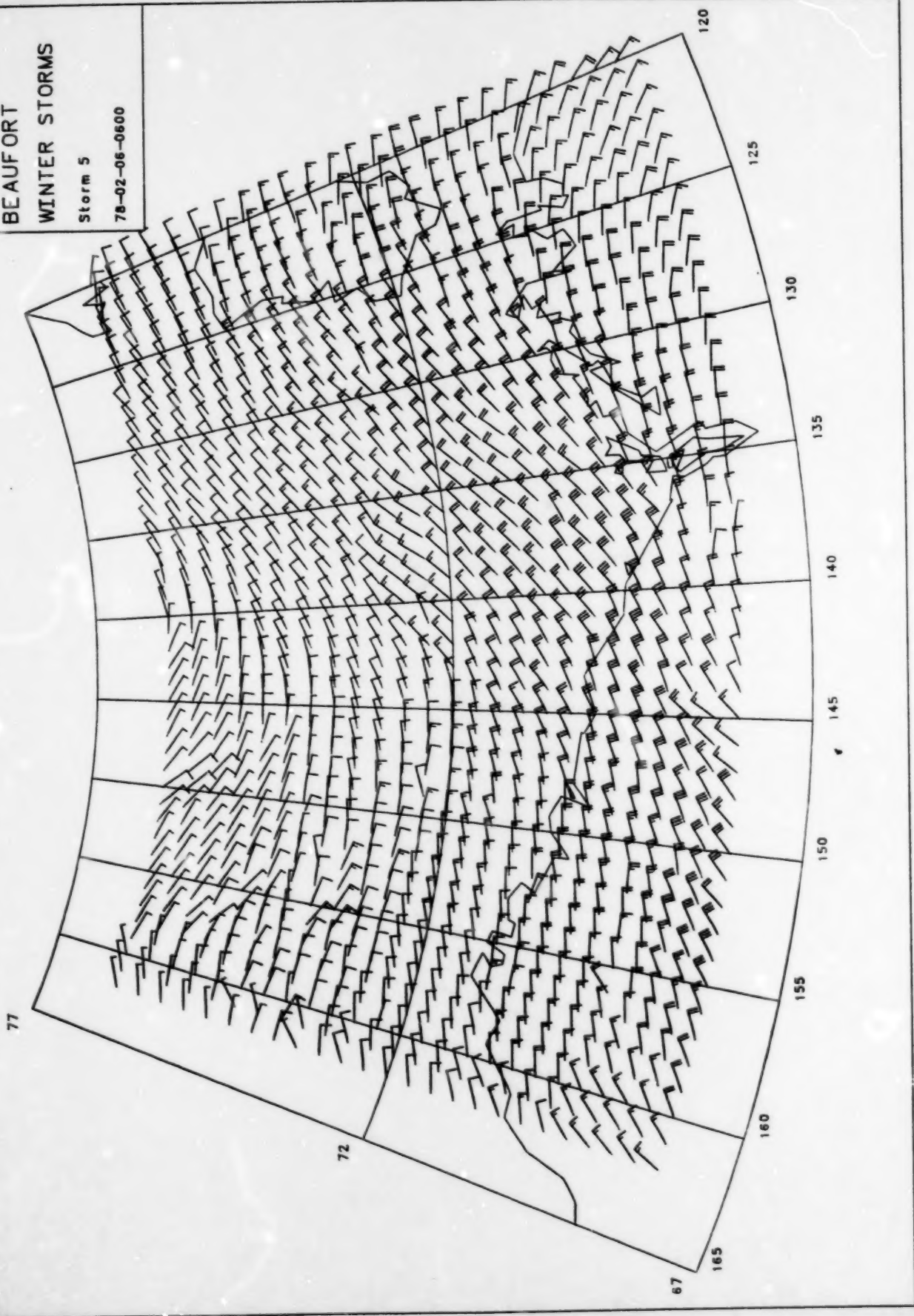


STORM # 5

BEAUFORT
WINTER STORMS

Storm 5

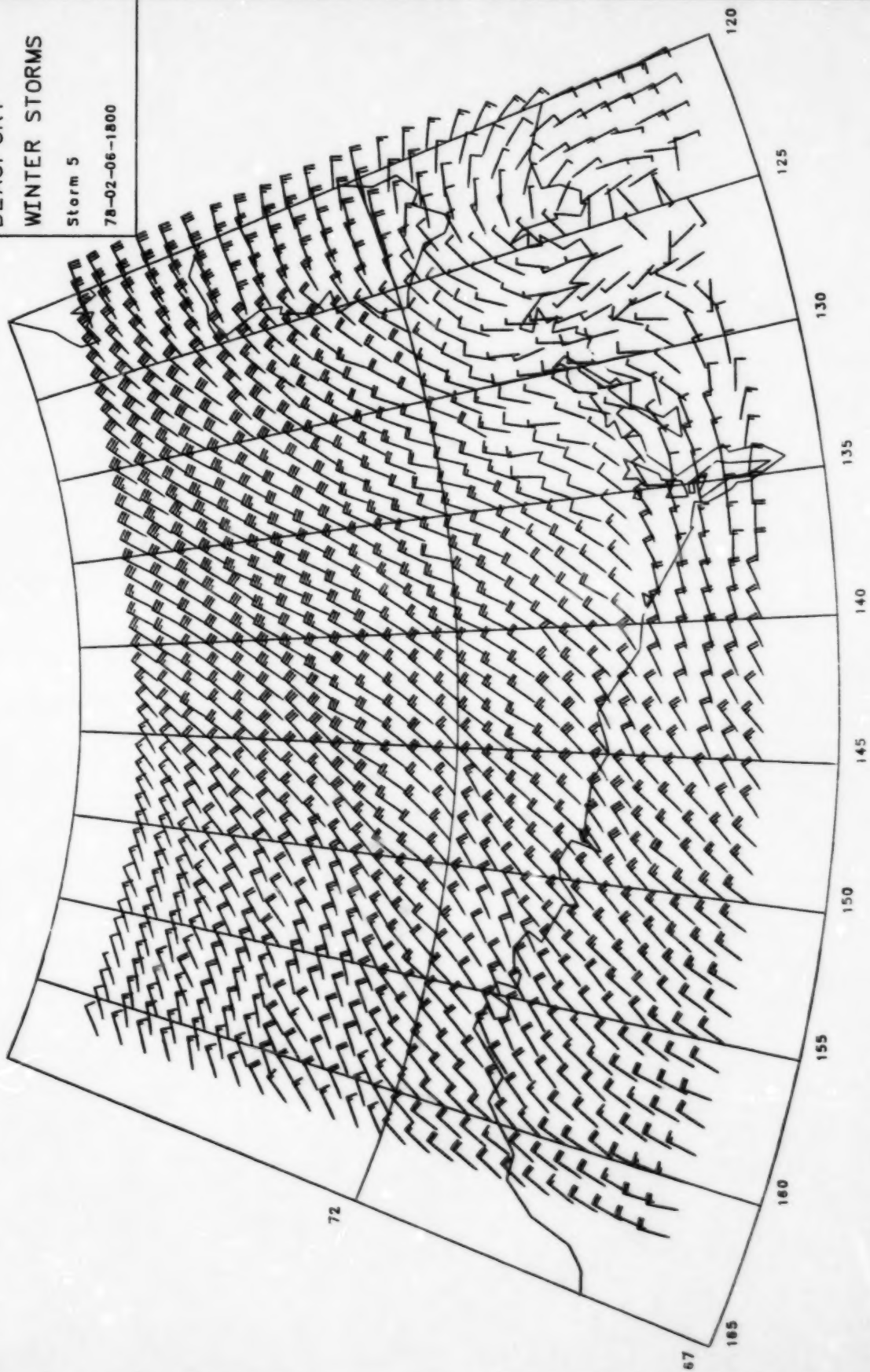
78-02-06-0600



BEAUFORT
WINTER STORMS

Storm 5

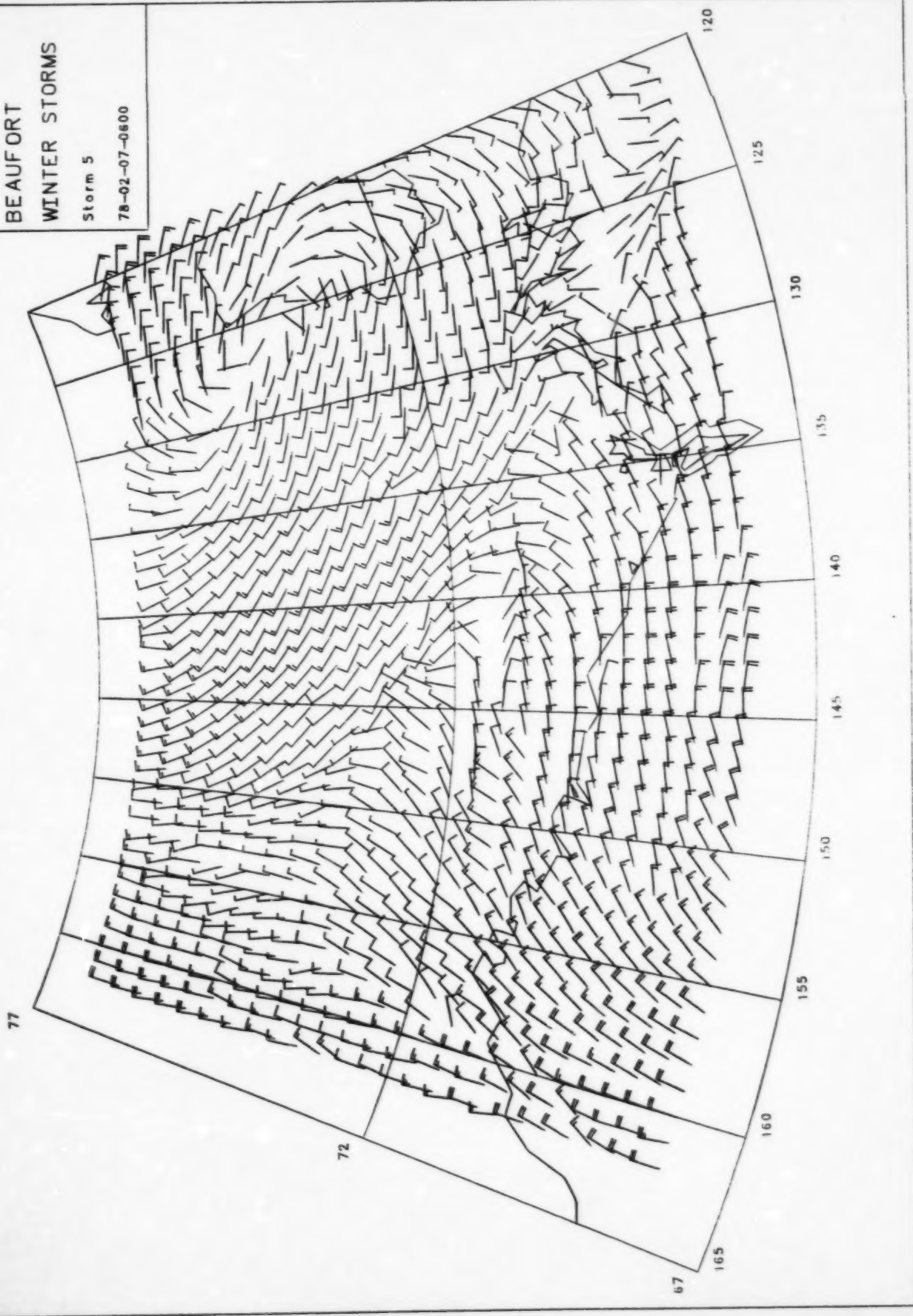
78-02-06-1800



BEAUFORT
WINTER STORMS

Storm 5

78-02-07-0600

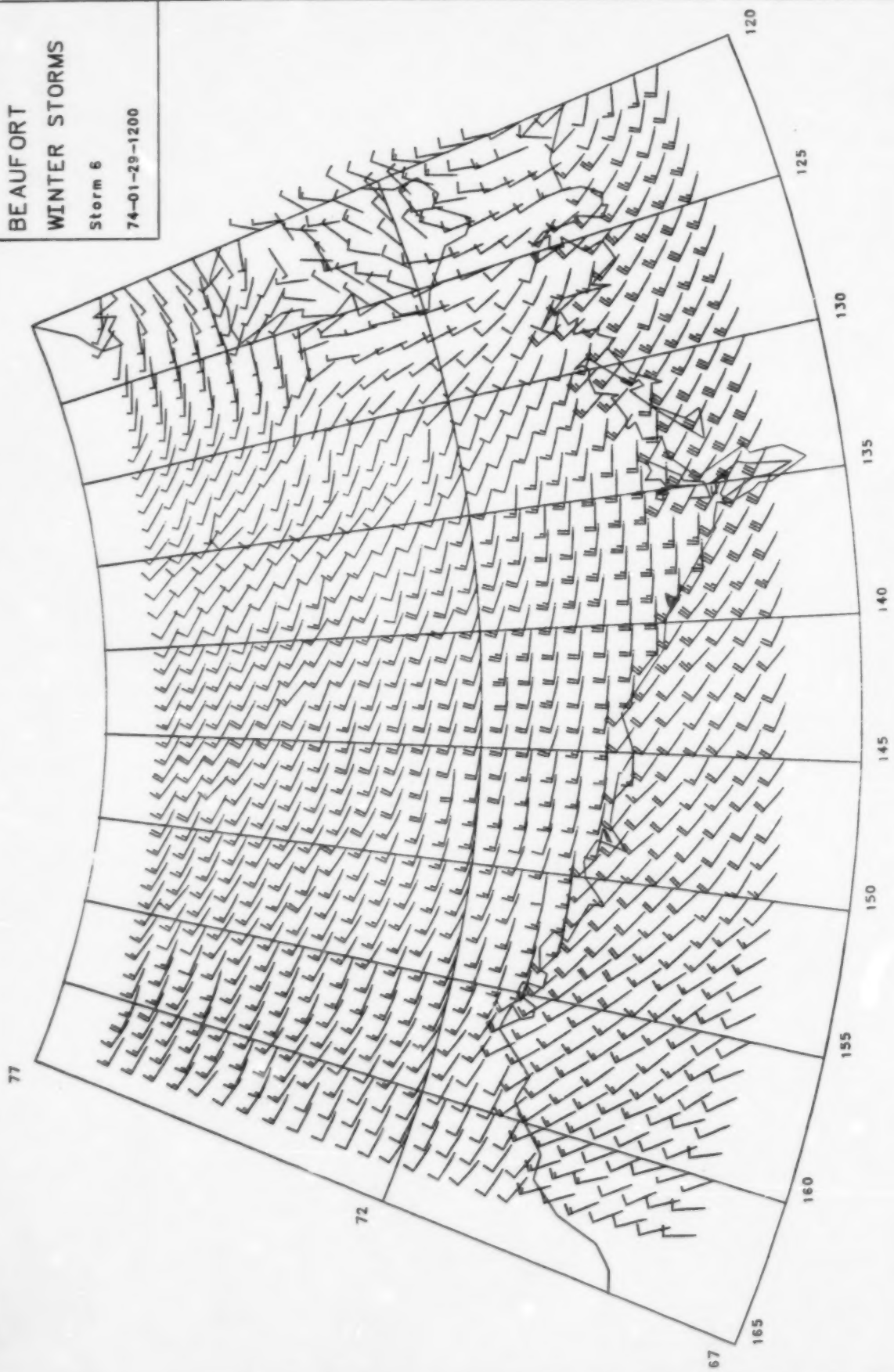


STORM # 6

BEAUFORT
WINTER STORMS

Storm 6

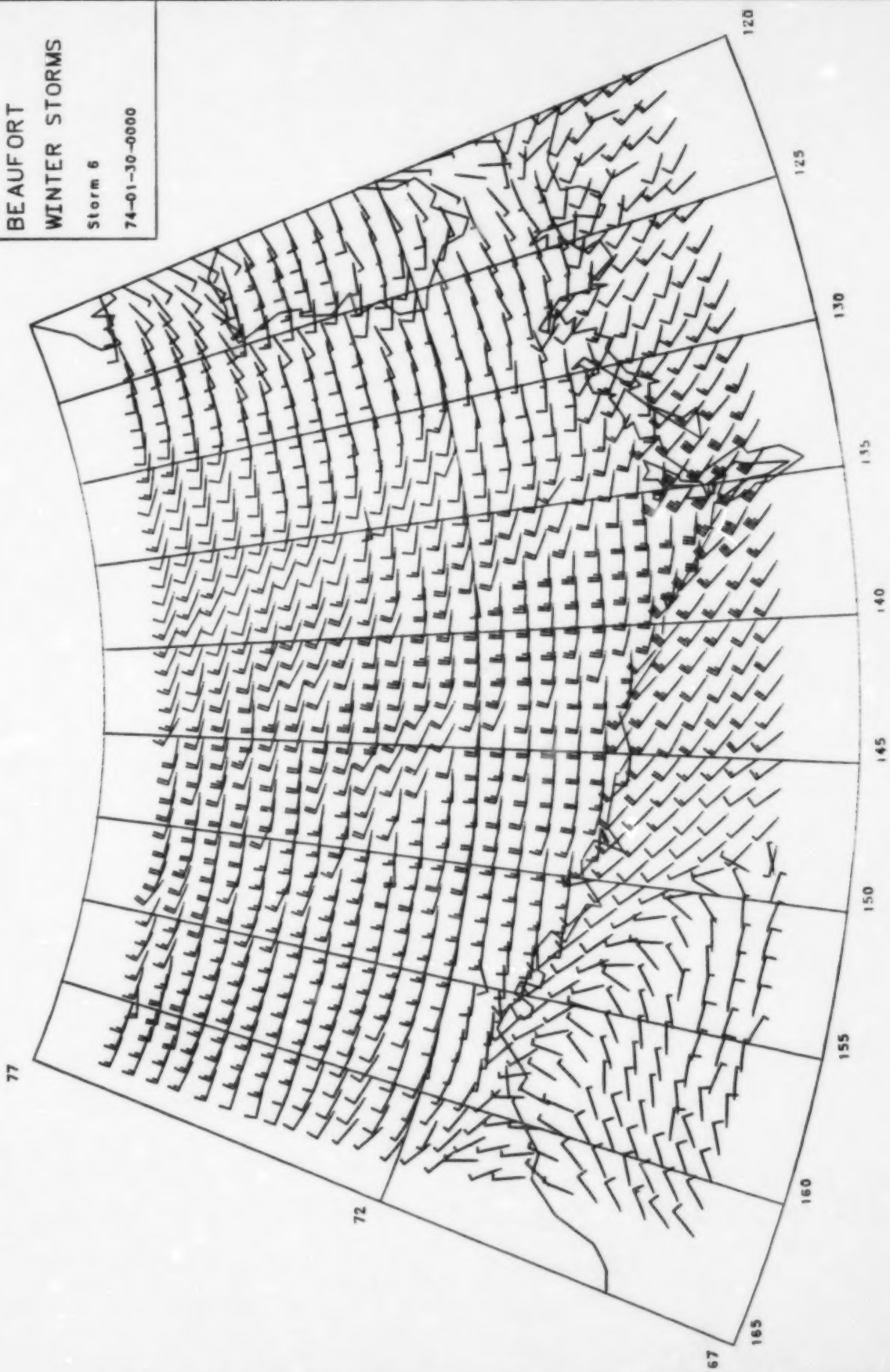
74-01-29-1200



BEAUFORT
WINTER STORMS

Storm 6

74-01-30-0000

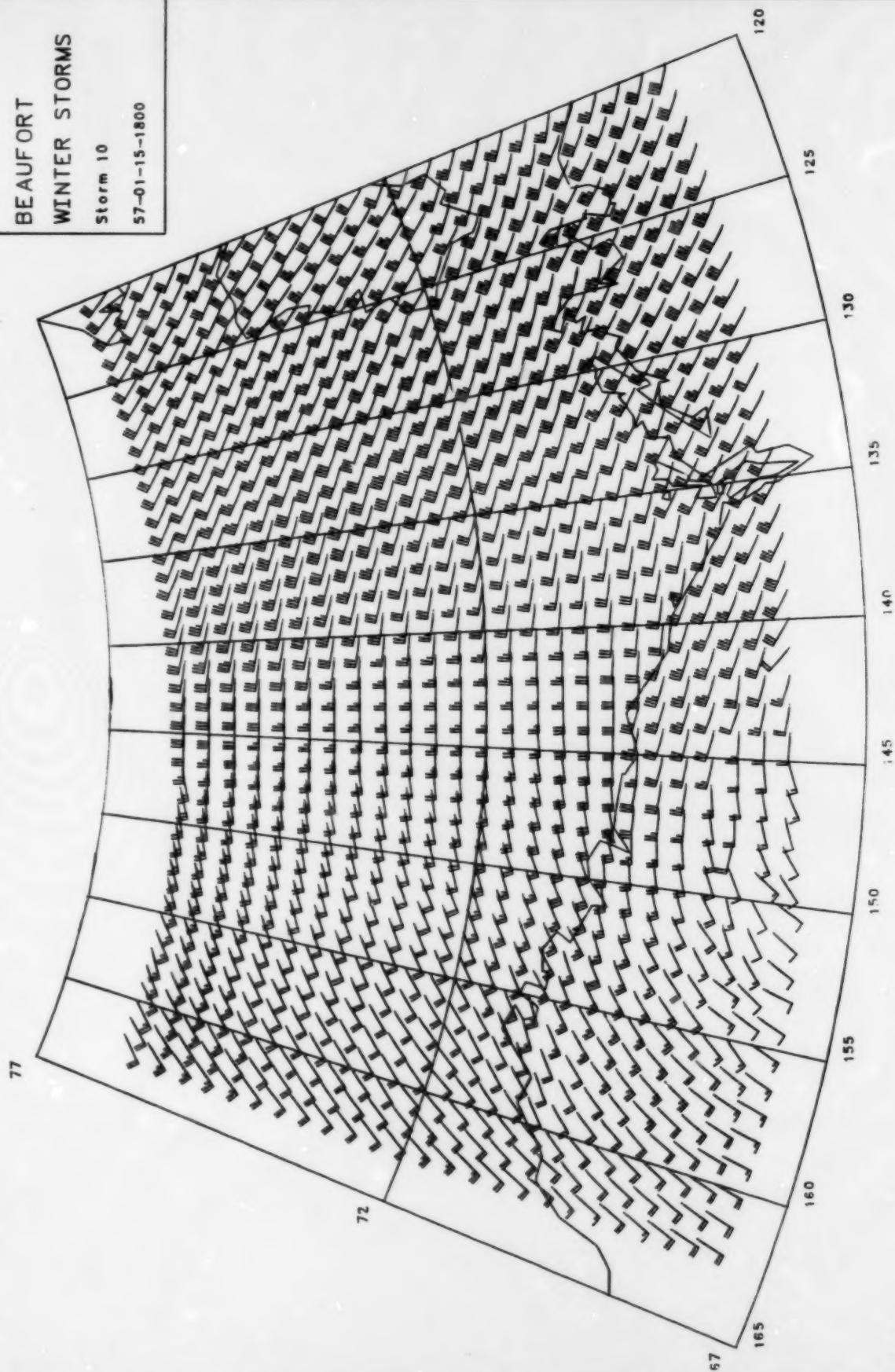


BEAUFORT

WINTER STORMS

Storm 10

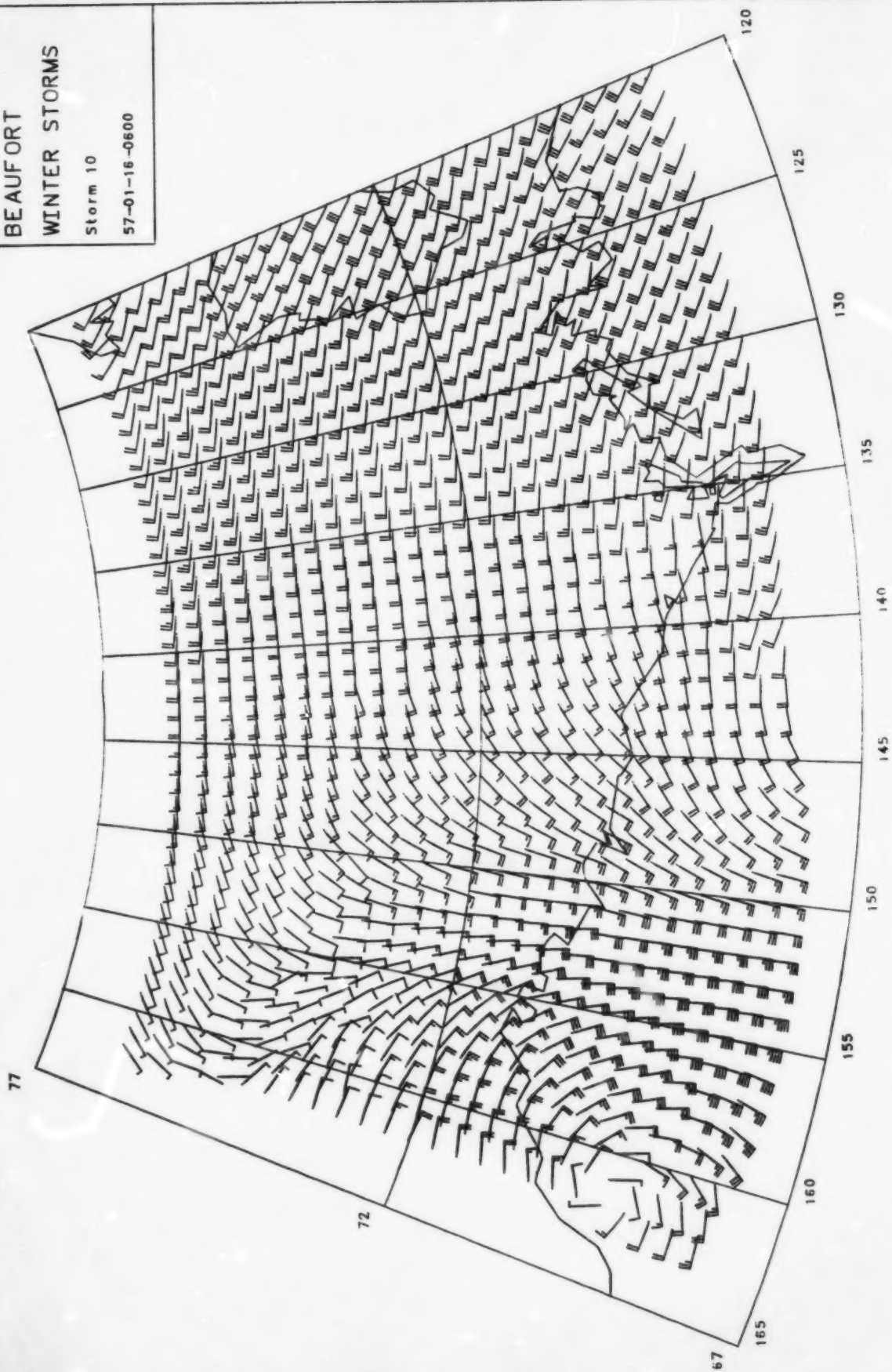
57-01-15-1800



BEAUFORT
WINTER STORMS

Storm 10

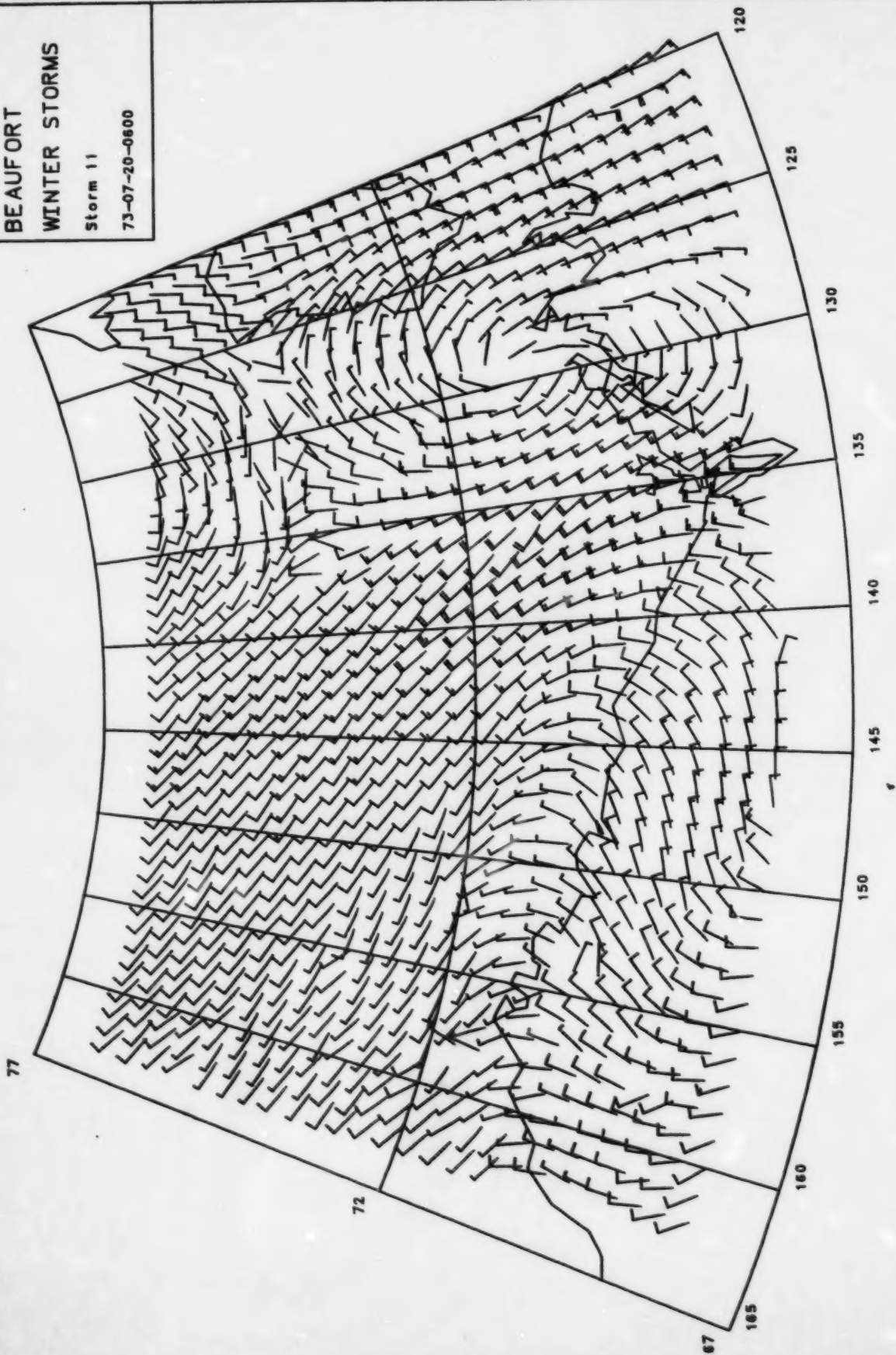
57-01-16-0600



STORM # 11

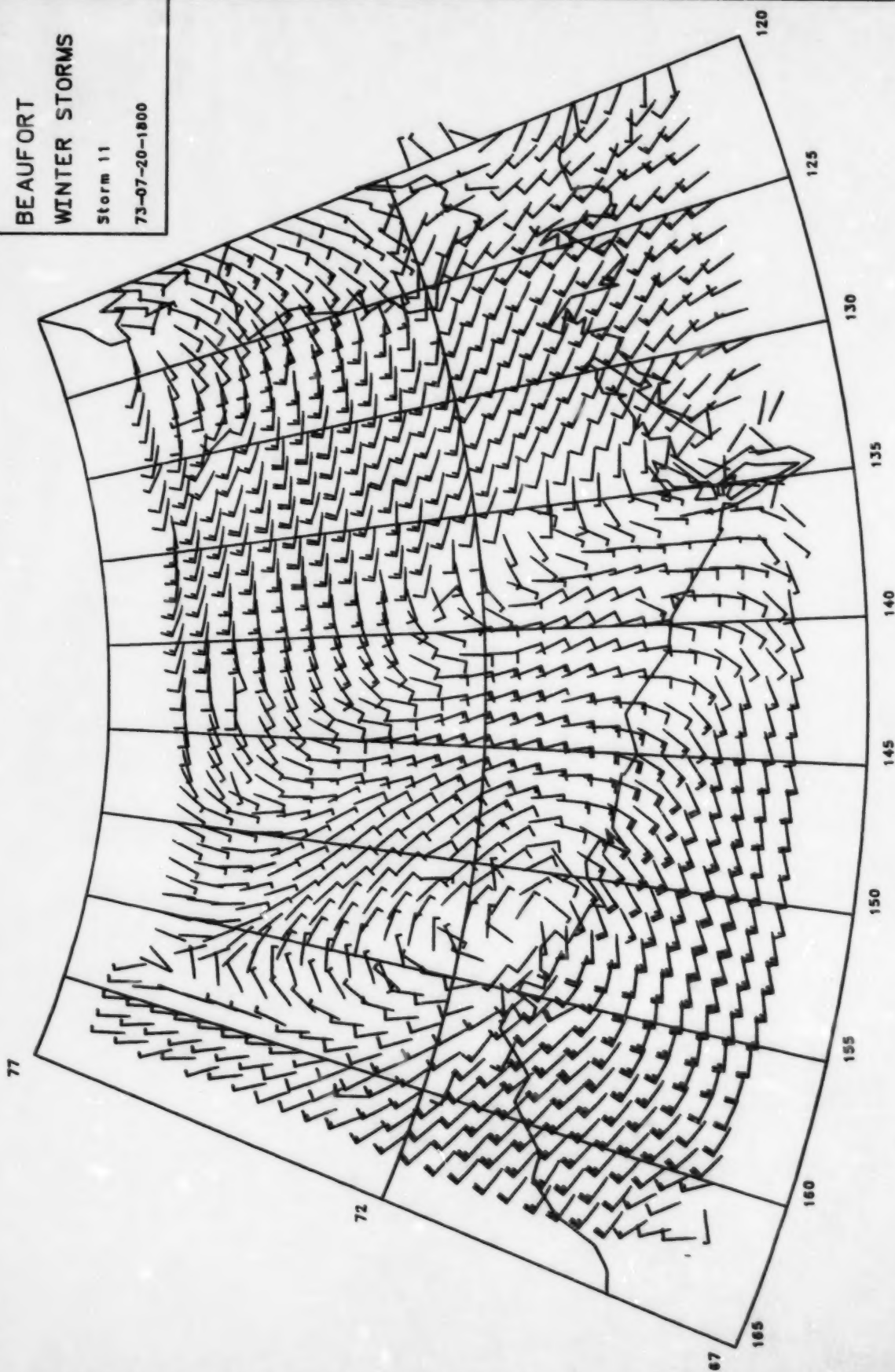
BEAUFORT
WINTER STORMS

Storm 11
73-07-20-0600



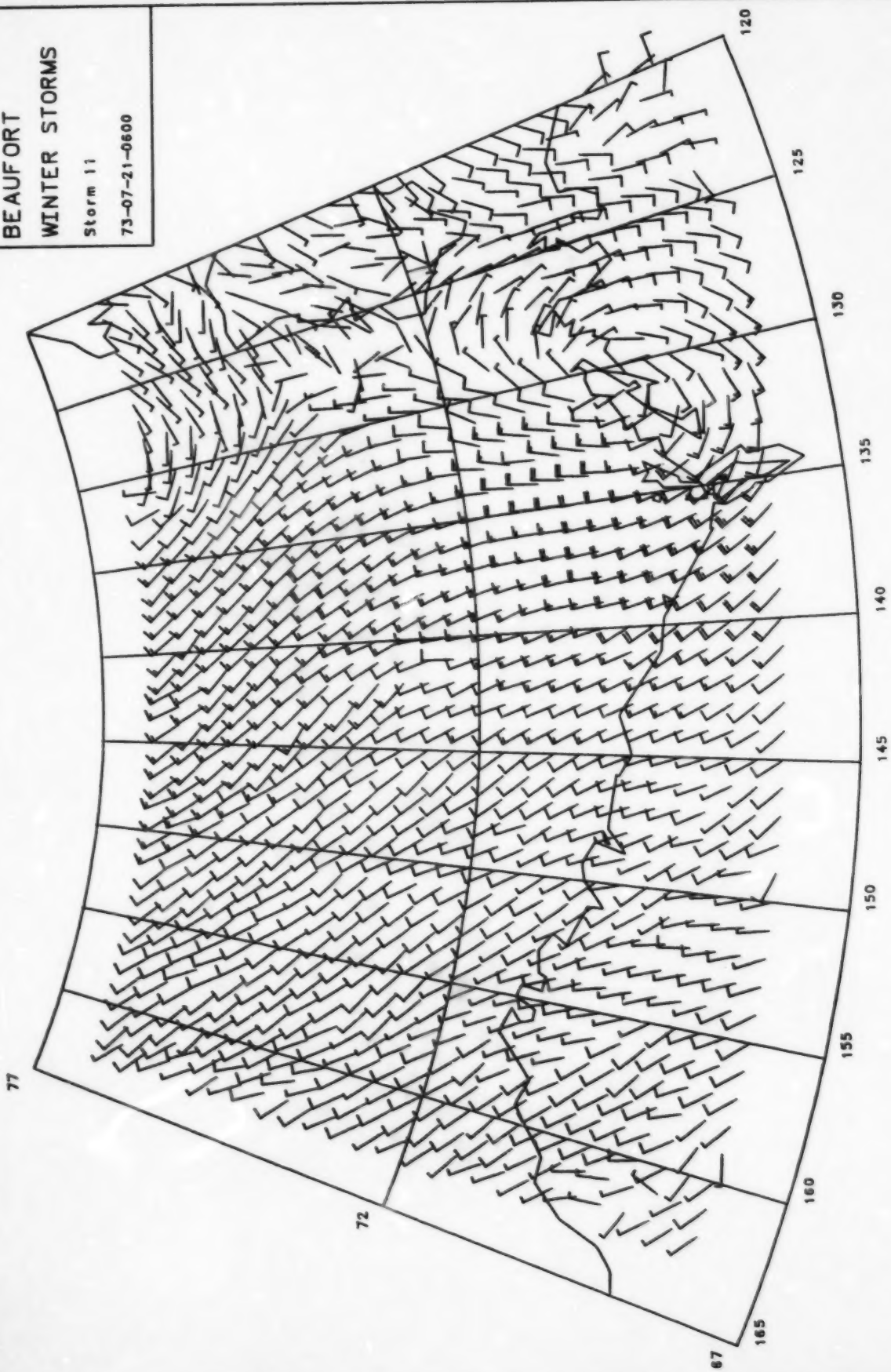
BEAUFORT
WINTER STORMS

Storm 11
73-07-20-1800



BEAUFORT
WINTER STORMS

Storm 11
73-07-21-0600

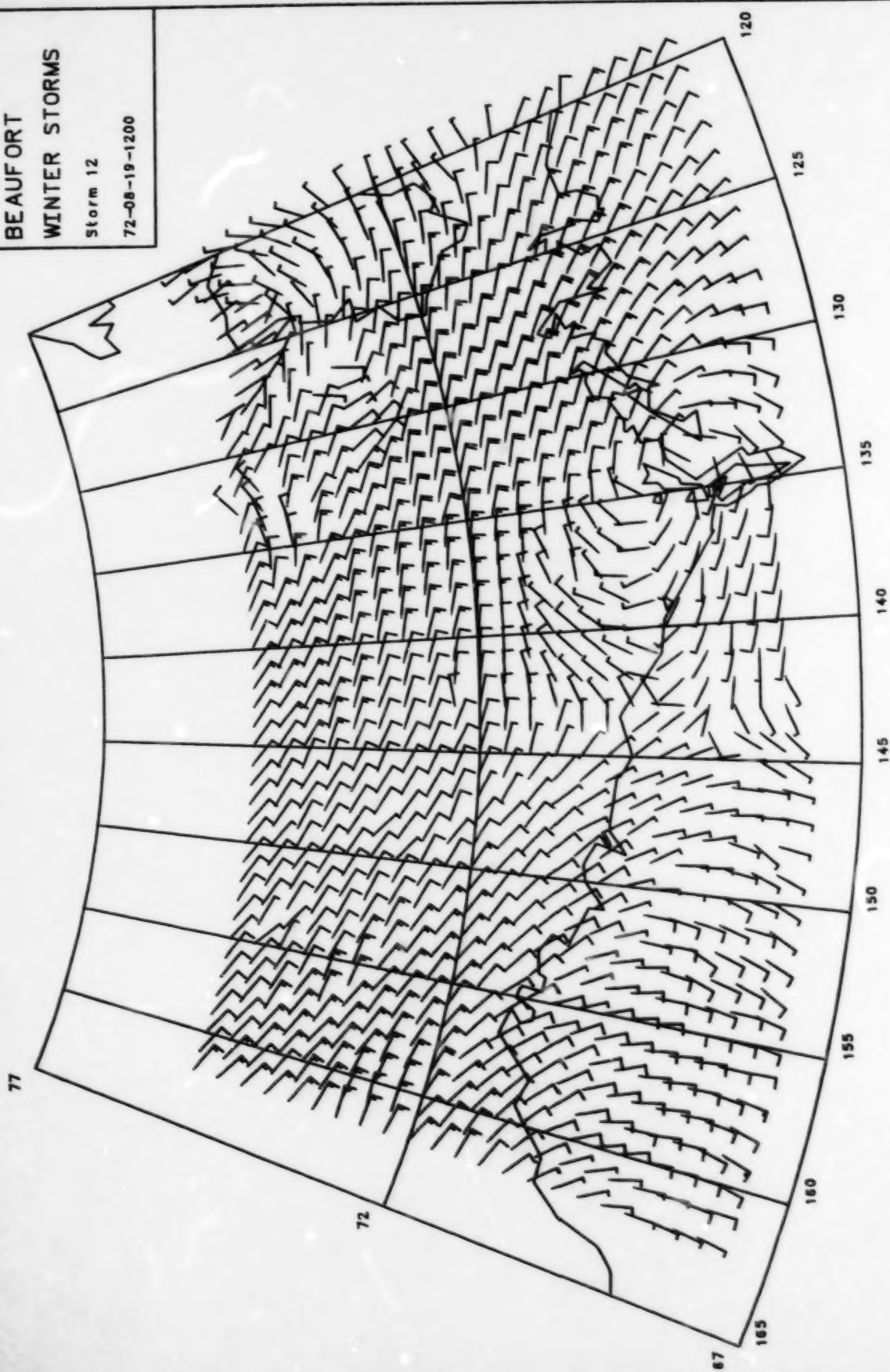


STORM # 12

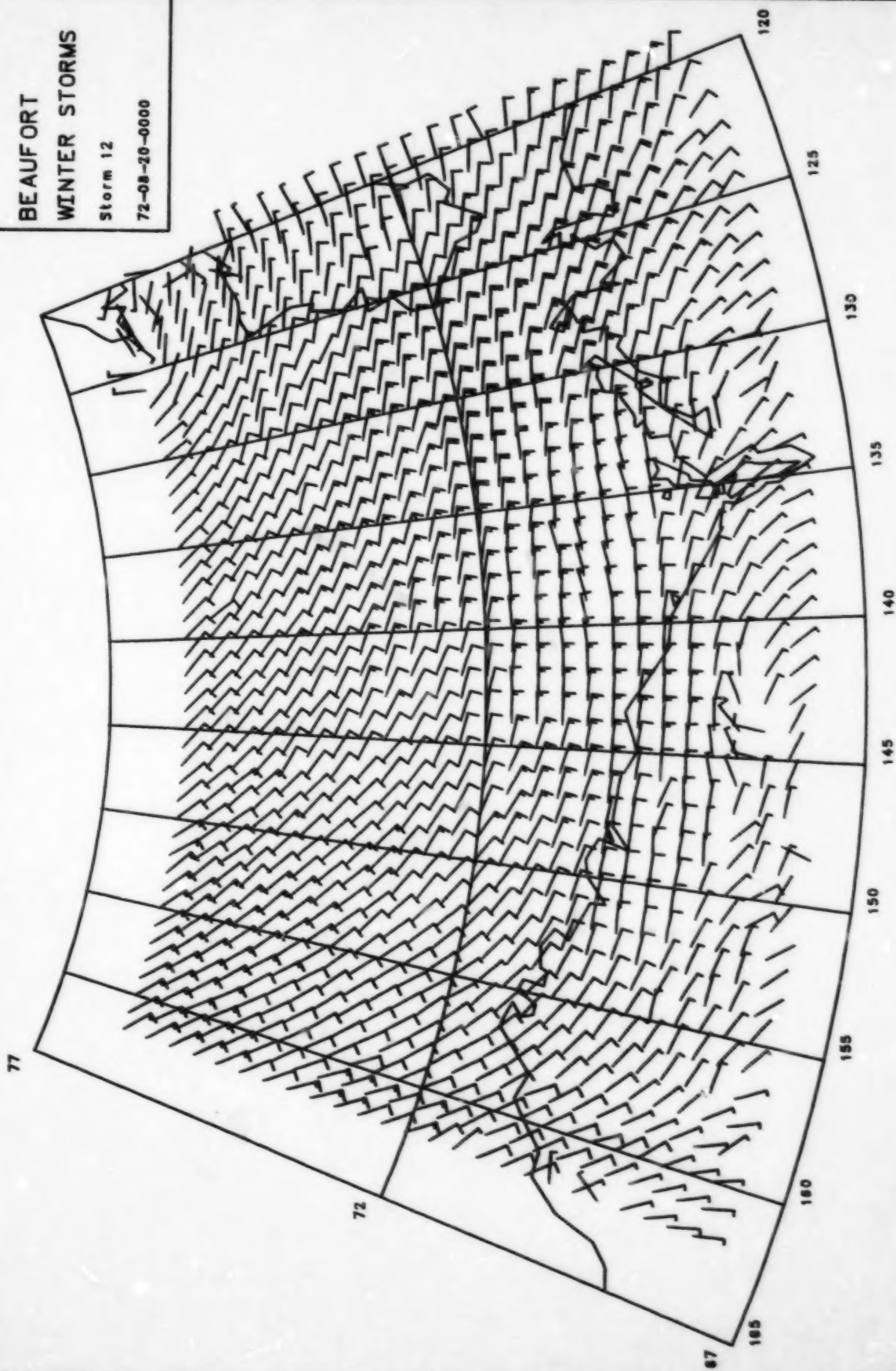
BEAUFORT
WINTER STORMS

Storm 12

72-08-19-1200

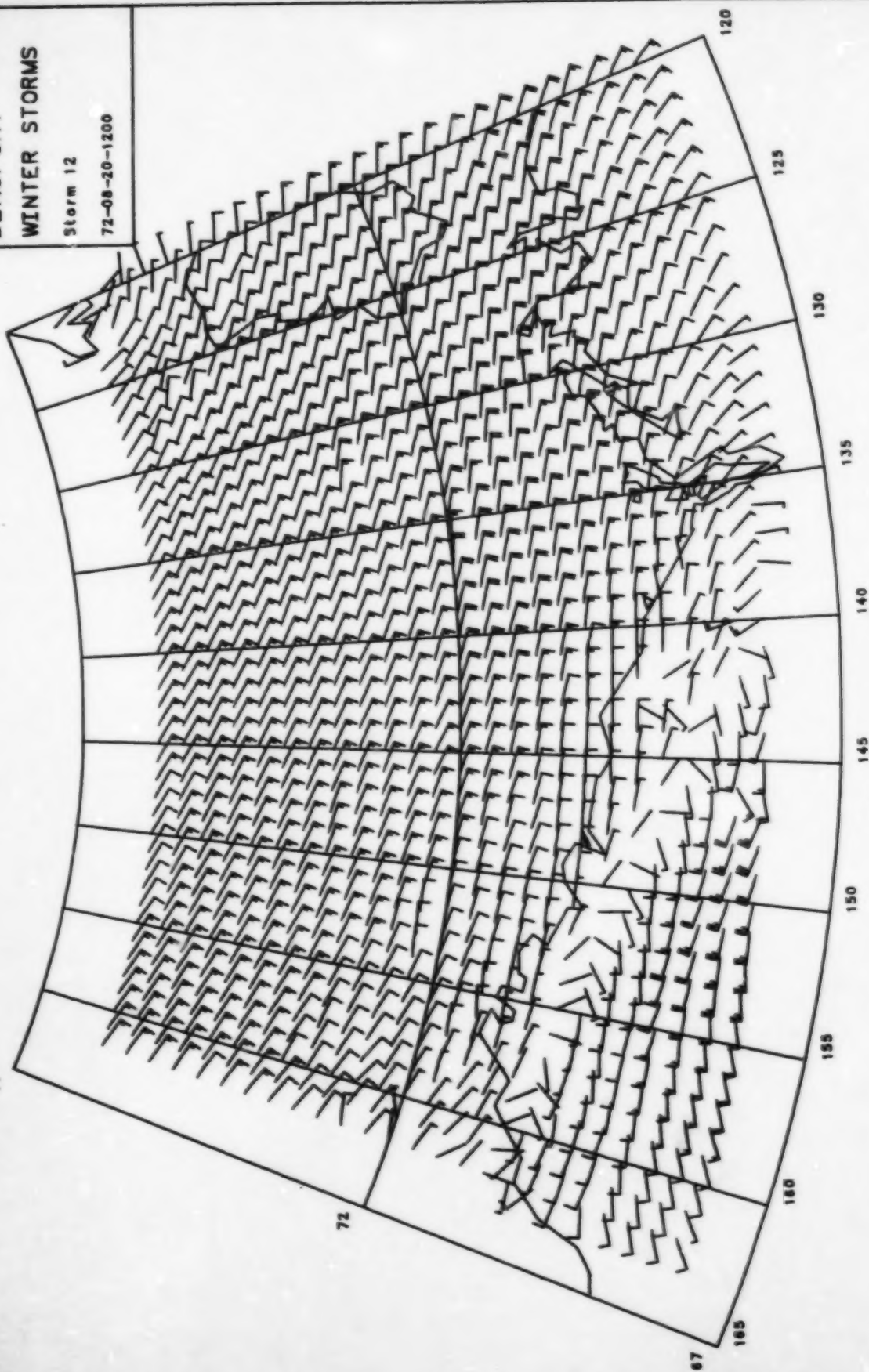


BEAUFORT
WINTER STORMS
Storm 12
72-08-20-0000



BEAUFORT
WINTER STORMS

Storm 12
72-08-20-1200

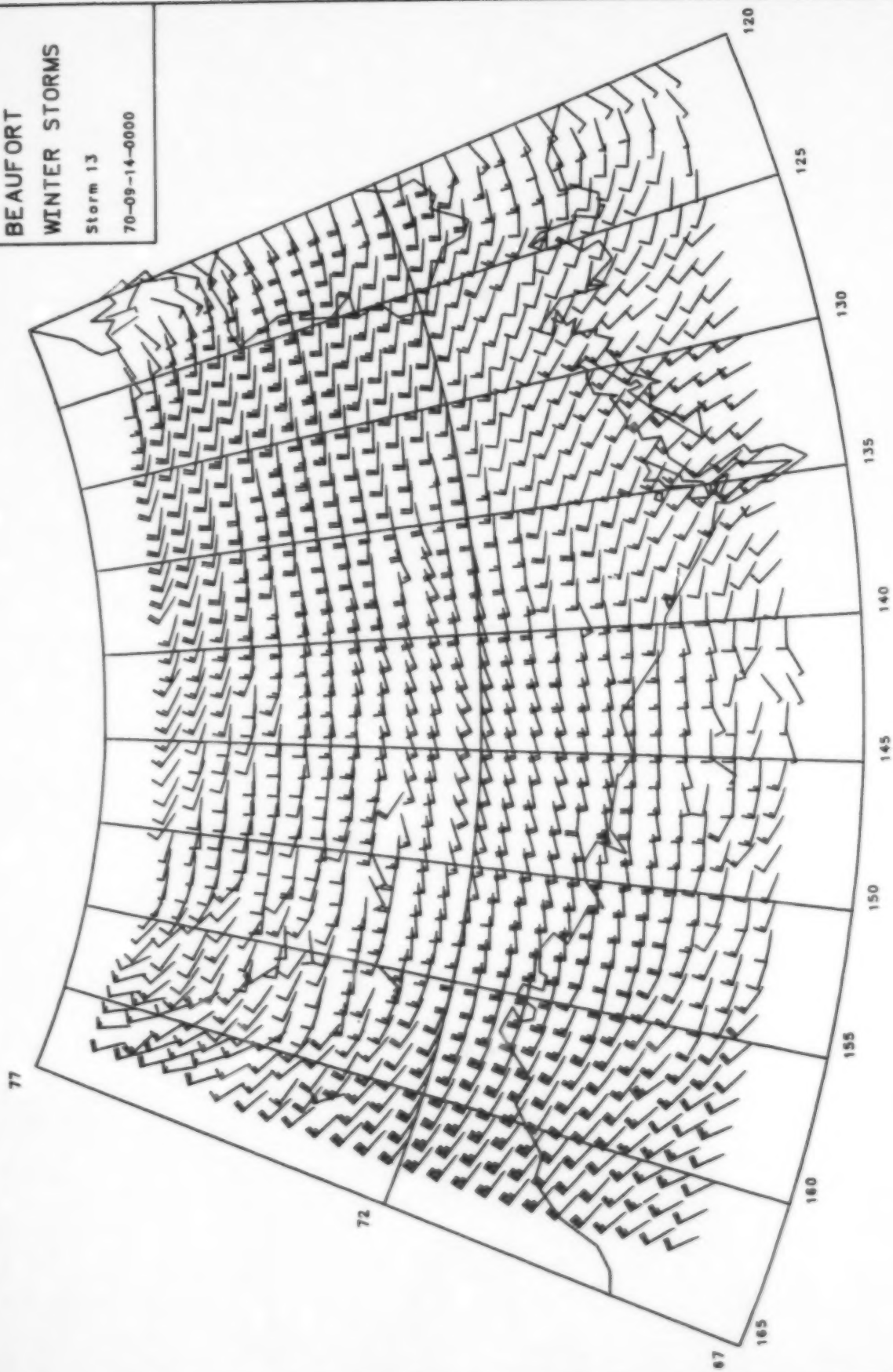


STORM # 13

BEAUFORT
WINTER STORMS

Storm 13

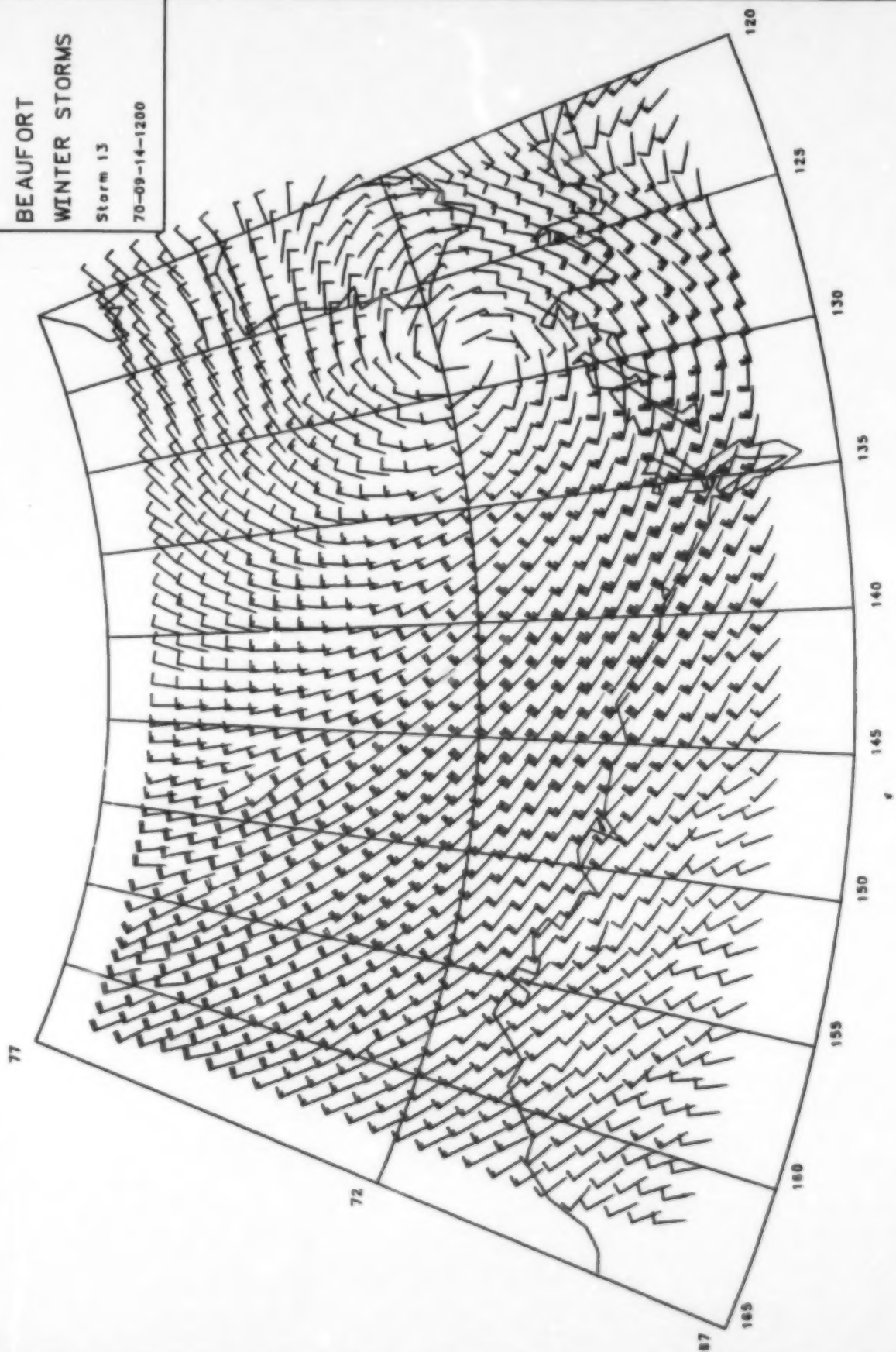
70-09-14-0000



BEAUFORT
WINTER STORMS

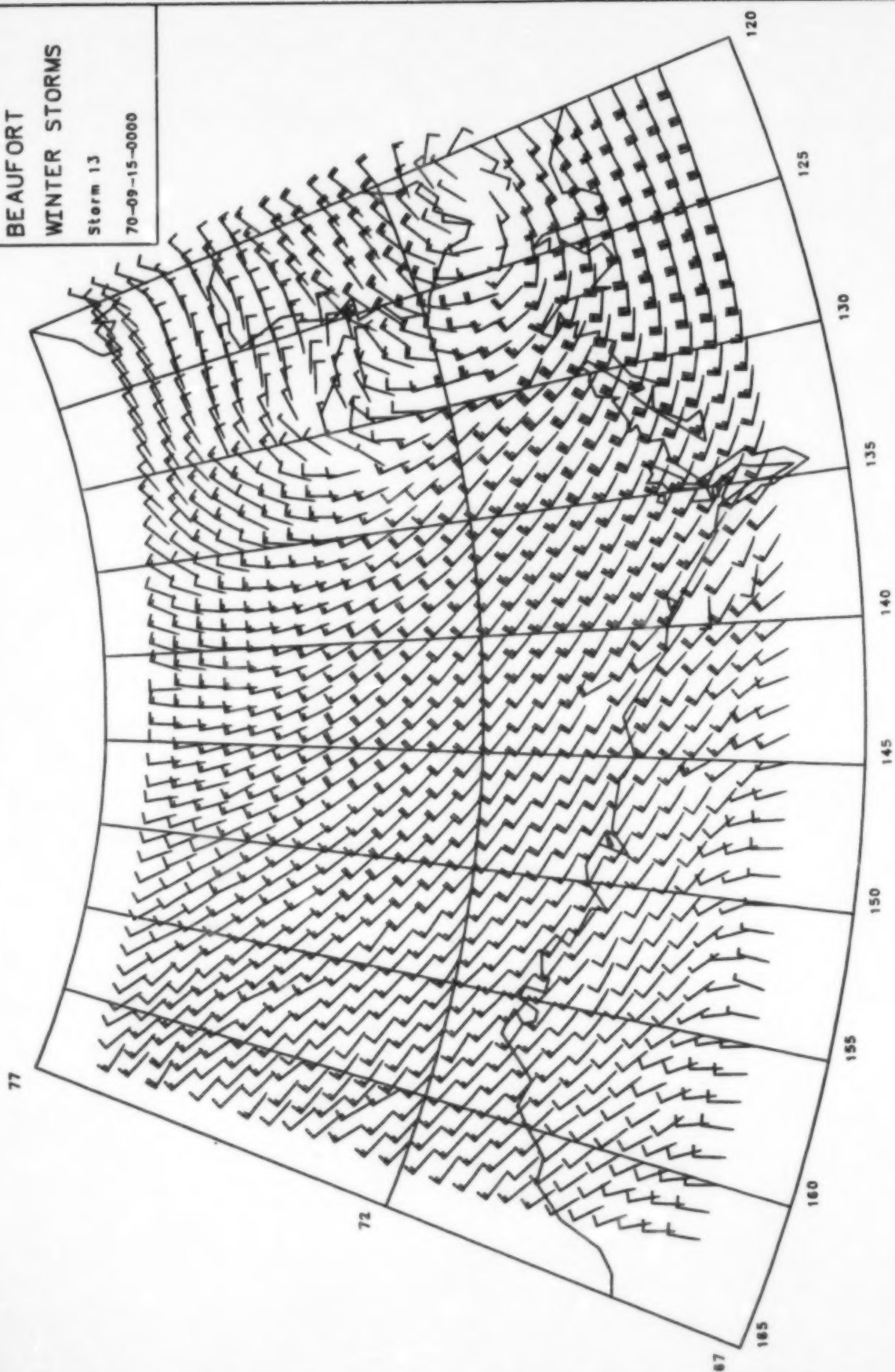
Storm 13

70-09-14-1200



BEAUFORT
WINTER STORMS

Storm 13
70-09-15-0000

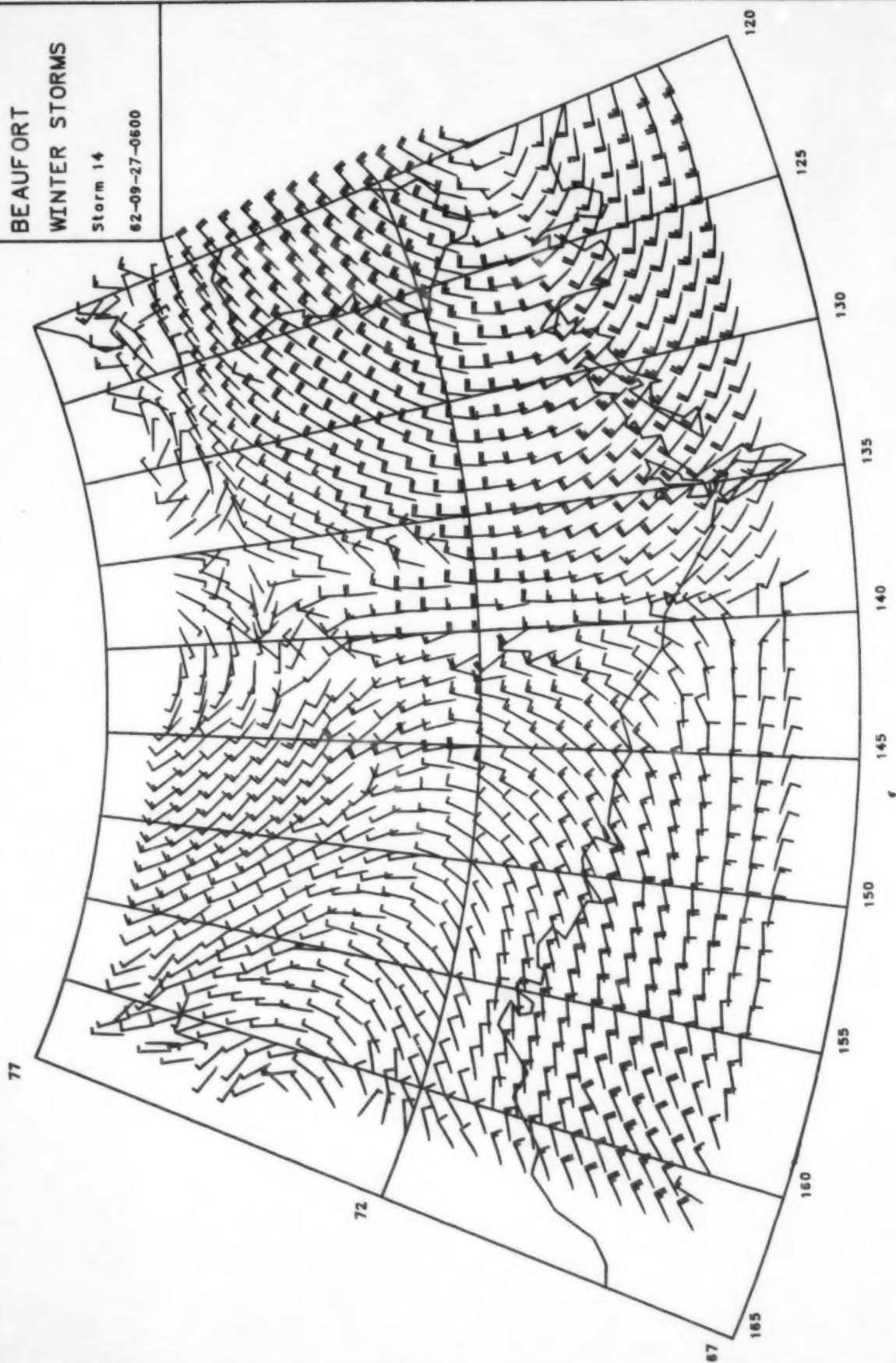


STORM # 14

BEAUFORT
WINTER STORMS

Storm 14

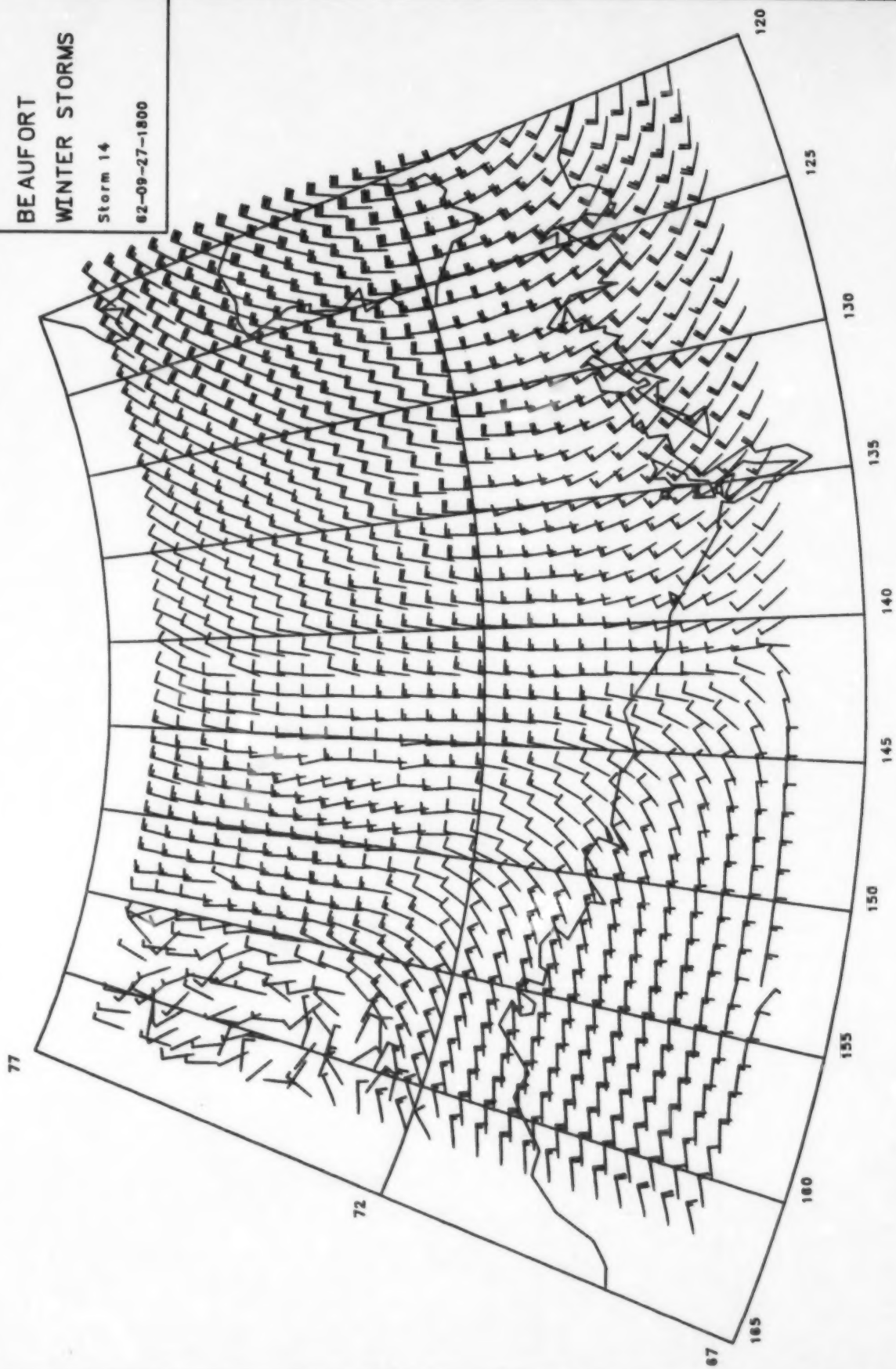
62-09-27-0600



BEAUFORT
WINTER STORMS

Storm 14

62-09-27-1800



BEAUFORT
WINTER STORMS

Storm 14

62-09-28-0600

